SCIENCE

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MSS. intended for publication and books, etc., intended for review should be sent to Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE
THE ATLANTA MEETING

UNDER the presidency of Dr. Edmund B. Wilson, professor of zoology in Columbia University, the sixty-fifth meeting of the American Association for the Advancement of Science, and the twelfth of the "Convocation week" meetings, was held in Atlanta from December 29, 1913, to January 3, 1914.

It seems to be almost impossible to obtain an accurate record of the attendance, chiefly because the members of the affiliated societies do not register. The number actually registered at headquarters was 324 members of the association, 54 members of affiliated societies and 16 delegates. Perhaps the total attendance, based to be sure on estimation, was about 500, a very good number when one remembers that Atlanta is rather out of the beaten track of tourists, but even if the number in attendance was not as great as at some of the previous meetings, and notwithstanding the rainy weather, the admirable arrangements and the enthusiastic reception accorded were more than compensation. With that characteristic hospitality of the south the people of Atlanta extended to the visitors a welcome that will long be remembered.

The following affiliated societies met during the week:

Astronomical and Astrophysical Society of America.
Botanical Society of America.
American Association of Economic Entomologists.
Entomological Society of America.
American Microscopical Society.
American Physical Society.
American Phytopathological Association.
School Garden Association of America.
Southern Society for Philosophy and Psychology.

On Monday evening the association formally opened its convention by the general session in Taft Hall of the auditorium-armory building. The meeting was called to order by the retiring president, Dr. Edward C. Pickering, who introduced the president of the meeting, Dr. Edmund B. Wilson. If anything was needed to assure the association of its hearty welcome, surely the letter of greeting sent by Governor Slaton, and the address of Mayor Woodward amply sufficed. After President Wilson's reply, Dr. Pickering delivered the annual address on "The Study of the Stars." This meeting was preceded in a delightful way by an organ recital through the courtesy of the Atlanta Musical Festival Association, Mr. Chas. A. Sheldon, Jr., being the organist. After the meeting the members and visiting ladies were entertained by a reception at the University Club.

On Tuesday from five to seven o'clock the visitors were received by Governor and Mrs. John M. Slaton at the governor's mansion.

Two evening lectures of the popular kind complimentary to the citizens of Atlanta were delivered. On Tuesday Dr. Chas. Wardell Stiles, of the U. S. Public Health Service, discussed "The Health of the Mother in the South," and on the following evening the subject of the lecture by Professor Chas. E. Munroe, of the George Washington University, was "The Explosive Resources of the Confederacy during the War and Now: A Chapter in Chemical History."

Numerous smokers, luncheons, and dinners and several excursions to near-by institutions and places of historical and scientific interest helped to add to the social pleasure of the week.

The different sections of the association and the affiliated societies met morning and afternoon for the reading of papers throughout the week or until the lists of titles were finished.

The vice-presidential addresses given before the sections were as follows:

Section A: "The Influence of Fourier's Series upon the Development of Mathematics," by Edward B. Van Vleck.

Section B: "The Methods of Science: To What do they Apply?" by Arthur G. Webster.

Section D: "Safety and the Prevention of Waste in Mining and Metallurgical Operations," by J. A. Holmes.

Section E: "Pleistocene History of Missouri River," by J. E. Todd.

Section F: "The Story of Human Lineage," by William A. Locy.

Section G: "The Evolution of a Botanical Problem," by Duncan S. Johnson.

Section I: "The Development of our Foreign Trade," by John Hays Hammond.

Section K: "The Physiological Instruction of Medical Students," by J. J. R. Macleod. (Read by title.)

Section L: "Science, Education and Democracy," by J. McKeen Cattell.

Among the more important actions taken by the Council, the following may be mentioned:

280 members and 200 fellows were elected.

On motion, the following resolutions offered by the committee on policy were adopted:

Resolved, That the council looks with favor upon the organization of a Brazilian division of the association, and that a committee on organization be appointed for this work with Senator Eduardo Braga as chairman.

Resolved, That the Society of American Foresters be formally accepted as an affiliated society.

Resolved, That the council of the American Association for the Advancement of Science authorizes the establishment of local branches of the association in places where the members are prepared to conduct branches which will forward the objects of the association.

Resolved, That the standing committee on organization and membership be instructed to promote the establishment of such local branches.

The associate secretary for the south made an interesting report of the work which he had undertaken towards stimulating an interest in the association in the south. He reported correspondence with several hundred men in southern institutions and a visit to several of the educational institutions of the south.

Dr. McDougal reported news concerning the Pacific Coast Division with reference to the Pacific Coast Meeting. A committee of thirty from this division has been given power to organize for the specific purpose of making preparations for this meeting. He also stated that the Pacific Coast Association of Scientific Societies, composed of three or four hundred members, had also taken this matter up. Members should come prepared to spend at least ten days in California, as meetings would probably be held in three or four different places in the state. The time of holding this meeting was discussed but no definite action taken.

Dr. Pickering and Dr. Holmes on behalf of the committee on expert testimony reported progress, but postponed its final report.

The permanent secretary read a letter from Dr. J. S. Diller, asking that a grant be made for the publication of the twenty-four papers read before Section E, on the Mineral Resources of the Southern States. On motion, a grant of $200 was appropriated for this purpose.

On motion, the permanent secretary and the editor of science were instructed to prepare a directory of the funds available for research work for the information of those desiring to make application for the same.

The president announced the members he had appointed on the committee of one hundred on research authorized at the spring meeting of the council.

On motion, a list of the members of the association, the constitution and the official proceedings were ordered printed during the year, and every three years thereafter, provided funds are available.

At the meeting of the general committee, the following officers were elected:

President: Chas. W. Eliot, president emeritus of Harvard University.

Vice-presidents:

Section A: Henry S. White, Vassar College.
Section B: Anthony Zeleny, University of Minnesota.
Section D: Albert Noble, New York.
Section E: U. S. Grant, Northwestern University.
Section F: Frank R. Lillie, University of Chicago.
Section G: G. P. Clinton, Connecticut Agricultural Experiment Station.
Section H: Clark Wissler, American Museum of Natural History.
Section K: R. M. Pearce, University of Pennsylvania.
Section L: Paul H. Hanus, Harvard University.
Section M: L. H. Bailey, Cornell University.

General Secretary: W. A. Worsham, Jr., Athens State College of Agriculture.

Secretary of Council: Henry Skinner, Academy of Sciences, Philadelphia.

Associate Secretary of the South: R. M. Ogden, University of Tennessee.

At this meeting it was decided to hold the next meeting of the association at Philadelphia, during convocation week, 1914–1915.

On motion it was recommended to future general committees that the meeting of 1915–16 be held at Toronto and the meeting

of 1916–17 in New York. It was further recommended that the New York meeting be a special meeting in which all affiliated societies should be invited to take part and that such general convocation-week meetings should be held at intervals of four years, the second to be in Chicago in 1920–1921.

At its last meeting the council passed a resolution extending its warmest appreciation and thanks to the local committee, to the citizens of Atlanta and all those who contributed so ably and willingly to the comfort and entertainment of the members.

Atlanta has been called the metropolis of the "New South" and those visitors who found time to visit some of its many interesting places and institutions went away with new impressions that were not the least assets of a most enjoyable and successful meeting.

H. W. Springsteen,
General Secretary.

THE METHODS OF THE PHYSICAL SCIENCES. TO WHAT ARE THEY APPLICABLE?[1]

It is generally expected that a retiring vice-president shall deal in his retiring address with one of two things, either some aspects of his own work or some of the important questions which are agitating his own branch of science. My excuse for doing neither of these is that I do not feel that my own researches are of sufficient general interest for mention at this time, and that the masterly address of Professor Millikan last year on the theory of quanta had made it impossible for me to add anything to perhaps the most important of the recent new developments in physical theory. In deciding to content myself with some general observations I find that I have exposed myself to two risks, one that of repeating ideas that I have before expressed, the other that of seeming to have borrowed from the very interesting and fruitful address of Sir Oliver Lodge at the recent meeting of the British Association.

We physicists may certainly look with satisfaction at the present condition of our science, for although it finds itself in a period of violent flux involving the possibility of the discarding or modifying of some of our most cherished notions, it still remains as the model for the other sciences, many of which it logically includes in itself. When we speak of the methods of physical science, we of course mean the experimental method, as that is what distinguishes modern science from that of antiquity, but we include not only the methods and instruments of observation but also our methods of thought and reasoning. If we are to class sciences by the instruments used, we shall find most of them to belong under physics. Thus astronomy, so long confined to the study of the positions of the stars in two coordinates on the heavenly sphere, made use almost exclusively of the telescope and the clock, as important in the physical laboratory as in the observatory, while the modern part of astronomy annexes to the telescope the spectroscope and the photometer, the bolometer with its attendant galvanometer and the most recent developments of the physical laboratory in measuring radiation, including the recently discovered liberation of electrons from metals by light. For over a century chemistry has depended upon the physical balance as its chief instrument of measurement, while to-day the chemist uses the thermometer and calorimeter, the manometer for gas and osmotic pressures, and all the instruments for the measurement of electrical current and difference of potential that the physical labo-

[1] Address of the vice-president and chairman of Section B—Physics—American Association for the Advancement of Science, Atlanta, December, 1913.

ratory can afford him. As for meteorology or cosmical physics, it has no instruments except those of the physical laboratory.

But even outside of the purely physical sciences, we see the application of their methods of experimentation. In the physiological laboratory we find not only thermometers, but accurate manometers for the measurement of the blood pressure, and registering instruments for all the rhythms of the various organs and the study of fatigue, with electroscopes and galvanometers for the study of the electrical phenomena connected with the nerves and muscles. In fact the fertile brain of the physiologist Einthoven has given back to the physicist the most sensitive galvanometer that he possesses in the beautiful string-galvanometer which is used to study the action of the heart by means of the electric currents connected with its beating.

The science of botany is one that in many of its methods seems very remote from physics, and the work of the systematic botanist whose main interest seems to be to collect and label different plants and file them away in herbaria seems the antipodes of the methods of the physicist. And yet we have now the subject of plant physiology, in the laboratories of which we see again the familiar physical instruments in new applications. But recently in such a laboratory I saw an artificial tree, constructed of glass tubes and porous porcelain, which raised water from a reservoir and evaporated it into the air in close imitation of a real tree. Here again the thermometer and hygrometer are of prime importance, while we may expect the calorimeter, which has become so very important in physiology in connection with nutrition, to play its part in botany as well. It is of interest to find that the direction of the vertical, which seems to be so important in connection with the growth of plants, is not mysterious, but that if the plant is subjected to centripetal acceleration in a whirling machine, its root will yield exactly as to gravity. Finally we must credit to botany the study of osmotic pressure, the laws of which as discovered by Pfeffer have opened an enormous field to the physicist and chemist.

Finally invading the domain of the mental sciences, we find in the laboratory of experimental psychology, which may be variously termed physiological psychology or psychophysics, the same physical instrument and new ways of applying them. However color is interpreted to the brain by means of the physical and physiological mechanism of the eye, its physical properties must be definitely determined before any progress can be made. Similarly the sense of hearing can not be examined with definiteness until physical standards of sound are forthcoming. The slight advance made in the study of the sense of smell is probably due to the lack of its specification in chemical or physical terms. And the favorite subject of study in this field, that of the time of transmission of nerve impulses or of the formation of judgments, depends on the most fundamental of physical instruments, the clock.

But it would be tedious, as well as unnecessary, to attempt to enumerate all the instruments that have been contributed to the other sciences by physics. Let us turn to the methods of investigation which have proved characteristic of physical science. The collection of examples of phenomena, and their arrangement in classes, is of course characteristic of all the sciences, of botany or of anthropology as of physics. But the essential idea in classification in physics is the quantitative method, which results in methods of measurement, and the invention of instruments for their performance. After this has become possible, the next step is to formulate a theory, which may be of two kinds, either an ex-

planation of the phenomena by means of simpler and more familiar phenomena, or what is more likely to be possible, a theory which is the mere description of the phenomena mathematically in quantitative terms. For example, perhaps the first natural phenomena to be observed were those connected with the recurrence of day and night, the seasons, and the weather. But how long was it before the simple hypothesis was formed of the rotation of the earth, to say nothing of its orbital motion around the sun! And until clocks were invented no very profound conclusions as to the constancy of the length of the day or year were possible. That the properties of space and time might be discussed by philosophers was to be sure possible, but their results would not carry great weight with the new school of natural philosophers. When Galileo deduced by experiment, and described with mathematical precision, the acceleration of a falling body, he probably contributed more to the physical sciences than all the philosophers who had preceded him.

The investigation of physical phenomena has been a most fertile source of improvement of mathematical methods, but this to me most alluring subject I have no time to develop, having treated it at length elsewhere.[1] Of this the most notable example is Newton's invention of the differential and integral calculus, which has given us probably the most powerful instrument devised by man for making discoveries. Without it no progress could have been made in the examination of continuously varying phenomena. Is nature continuous or not, that is, in the neighborhood of every point of space within a distance no matter how small, are there as many other points as we please, and may a similar statement be made for time? Is matter continuous, and do all varying quantities vary continuously? This I do not intend to discuss, referring you to Sir Oliver Lodge, who took that for his subject. But whether nature is continuous or not, it is extremely convenient to postulate that it is so. We are thus enabled to describe phenomena by means of differential equations, explaining or describing what happens at any point of space and time in terms of what is happening at the infinitely near ones. This has been then the most important of our ways of thinking about physical phenomena. For upon this we have based the method of dynamics, so auspiciously begun by Galileo and perfected by Newton. Galileo gave us the notion of acceleration, very important for a single body, but Newton completed it by that of force, which enables us to describe the actions of one body on another. Let me point out to you that what Newton did in connection with gravitation was not to explain it in the sense of telling what its cause is, but, as I have stated above, to describe it in exact mathematical terms. But, much more than this, Newton, by his succinct statement of the laws of motion, gave us the possibility of the explanation of a vast number of recondite phenomena in terms of the more familiar ones of dynamics.

The dynamical method then became the most important of physical methods of explanation. Here mathematics, by some thinkers considered, as Huxley said, to be "that science which knows nothing of observation, nothing of experiment, nothing of induction, nothing of causation," has rendered invaluable services. It is true that mathematics can not turn out more than is put in, but it can transform the data in a wonderful manner. Thus proceeding from Newton's definition of force, it led to the notion of energy, and eventually to the conception of the conservation

[1] Presidential address, American Physical Society, *Physical Review*, 1904.

of energy. To be sure, the notion of energy could not become of universal application until justified by multifarious experiment, and yet this has now come to be a principle in which we have more confidence than any other, not only in physics, but in all the natural sciences. But the principle of energy is not the only generalization of mechanics, nor in fact is it sufficient for the establishment of the equations of mechanics. A more general one is found in the so-called principle of least action, established upon a secure basis by Hamilton. From this principle all that we know of dynamics can be deduced, and by dynamics thus defined all the phenomena of celestial mechanics can be explained, with an accuracy almost beyond belief, the single law of the inverse square sufficing for all heavenly phenomena with an accuracy probably beyond that of our description of anything else in nature.

As one of the triumphs of the dynamical method in the explanation of recondite phenomena must be mentioned Maxwell's theory of the electromagnetic field, leading him to the discovery of the electromagnetic nature of light, and the prediction of electromagnetic waves. But in spite of this and other triumphs, the dynamical method alone was not sufficient in many cases.

Chemistry remained intractable by its means, and all the phenomena involving heat seemed outside its range. But it was at this very point that a powerful addition to the dynamical method came to its aid. As remarked above, the principle of conservation of energy would not have become so intrenched had it not been for its experimental confirmation, especially in the domain of the relations between heat and work, as carried out by Joule. The principle of equivalence, which has since been considered as the first law of thermodynamics, then, extended the dynamical generalization to a far larger field, and explained the disappearance of dynamical energy by its reappearance in the form of heat. But even then certain phenomena remained intractable by dynamical means, such as the well-known phenomena of heat conduction. To turn aside for a moment, the treatment of heat conduction by Fourier furnishes an admirable example of a merely descriptive theory, in which everything is exactly described, but it is of no moment for the theory whether heat is a fluid substance, a form of energy or an agitation of molecules. The laws of flow of heat, although merely descriptive, by analogy led to other great generalizations, notably in connection with the flow of electricity and with magnetism and electrostatics.

The method of analogy, always an attractive but dangerous one, led in connection with heat to a generalization which led to possibilities that dynamics could not furnish. The analogy of the working of water in a mill by falling from a higher to a lower level led Carnot to a conclusion, which though based on an imperfect analogy, led to most important results regarding the possibility of thermal changes. From his statement regarding the efficiency of heat engines, as based upon the fall in temperature of the heat employed, has resulted the second law of thermodynamics, or the principle of entropy, which together with the principle of energy has given us a method of enormous power, which may be indeed extended to those sciences toward which the dynamical method has shown itself as yet powerless. It was to the methods of thermodynamics that chemistry was destined to yield, largely through the efforts of our countryman, Willard Gibbs, and of Helmholtz. The reason for the failure of dynamics alone in chemistry may be stated as follows. The method of dynamics requires the complete specification of a system

in terms of a certain number of variable parameters, in terms of which two energy functions may be formed, one involving both the parameters and their velocities of change, and called kinetic energy, the other the parameters themselves only, and called potential energy. Now since we can not see the atoms or molecules, and do not know how they move, we can not form these energy functions, and hence can not form the differential equations. But by means of the principle of equivalence, we may determine the *sum* of the energies, by allowing them to be transformed into heat, and measuring this in a calorimeter. For this purpose we have the valuable thermochemical material of Julius Thomsen and others. But later other methods were devised of holding chemical reactions in equilibrium, and making them go in either direction reversibly. For instance, a salt, which would dissolve in water or an acid with the emission of heat, could in an electrolytic cell, to which a balancing electromotive force is applied, be dissolved or removed from the solution. By distillation the salt could also be removed from the solution, while the use of the semipermeable diaphragm and the methods of osmotic pressure introduced by van't Hoff furnished a variety of methods for the calculation of the energy involved, and the separation of it into two factors, one analogous to a force and the other to a displacement, leading to the definition of chemical affinities. This necessary step being taken, and Rayleigh and Gibbs having shown how the entropy could be computed, the methods of thermodynamics became applicable, and chemistry came under the domain of mathematical treatment.

During all this time the question had been many times asked whether the second law of thermodynamics and the properties of entropy could not be deduced from purely dynamical principles, so that thermodynamics should be brought under the classification of dynamics. To this question a negative answer had always been returned, although Helmholtz had described a certain sort of system for which the law of entropy applied. It was not until the development of a new method in physics, which though using the principles of pure dynamics, went much farther, that this end seemed to be attained. This was the so-called statistical method, which becomes every day more important, and may sooner or later supersede some of our classical methods involving differential equations. The first example of this was afforded by the kinetic theory of gases, in which the properties of a gas were explained by considering it to be instead of a continuous body, an aggregation of a huge number of small similar molecules, moving about with great velocities in all directions, and by their impacts on each other and the sides of the containing vessel causing the pressure. It was at first the custom to treat them as if moving all with a common velocity, the directions being distributed at random, but to Maxwell occurred the happy idea of applying the principles of probability or statistics, the method namely of averaging up the actions of a great number of individuals of which we know little or nothing singly. For instance, we know nothing of the direction or magnitude of the velocity of any particular molecule, nor of the direction joining the line of centers of two colliding molecules, but we may assume, since we know nothing to the contrary, that all velocities and directions are represented, and that there are fewer individuals possessing very large or very small velocities than those having some mean velocity. The only laws of mechanics made use of were that between impacts the velocity of a particle was constant, and that in each impact the momentum and energy

were conserved. The important thing then was the application of the laws of probability, and by this means Maxwell was led to show that in a steady state, that is, one independent of the time, the velocities were distributed according to the so-called law of errors. As this law is so important, permit me to give the familiar example which illustrates the main points of the discussion. Suppose we have a vertical board into which are driven a large number of horizontal pins regularly arranged in symmetrical diagonal lines. If now we allow shot to fall from a funnel above the middle of the board, a shot striking any pin will fall either to the right or the left. Of course the circumstances will, according to the laws of dynamics, determine in each particular case which way it will fall, but if we know nothing more about them we can only assume that it is equally likely to fall either way. The next time it strikes the same thing is the case, and the question arises what will be the effect of a great number of similar causes each equally likely to act one way or the other. The answer is simple. Evidently there will be more shot that will fall directly below than toward either side, and the distribution will be symmetrical on both sides, falling off to nothing at great distances. If we should find that the distribution was unsymmetrical we should immediately infer that there was something unfair about the apparatus, for instance, the pegs were different on one side from the other.

Let me here diverge for a moment to point out that here is a method which is as applicable to biological phenomena as to dynamics, and that by its means the resultant of a large number of causes acting at random may be investigated. The essential of the method is that one of two effects is held to be as likely as the other. If we consider a large number of similar objects, say beans or shells, measure their length or some characteristic feature, the different values will in general be distributed according to the law of errors. If not, our assumptions as to what is equally likely are not true. This statistical method is of the greatest use in anthropology and in the study of inheritance, now such an important part of biological study. It is true that the biologist may object that this method is a purely mathematical one, and is not borrowed from physics. This I shall not stop to discuss, merely pointing out where the same method is applicable to both physical and biological phenomena.

To return then to the application of statistical methods to dynamics. Besides the law of distribution of velocities, Maxwell was able to show that if molecules of two or more kinds were admitted to the same space then when statistical equilibrium was attained the mean kinetic energy of the different types of molecules would be the same, thus leading to a dynamical explanation of the law of Avogadro, one of the most important of chemical laws. Boltzmann, taking up the subject at this point, pushed the generalization of Maxwell farther, and applied it to individuals each more complicated than the simple molecule, and was able to show how a system not in statistical equilibrium tends to approach that condition. Furthermore, he defines a certain function of the state of distribution which continually tends to increase, thus having the same property as the entropy of a system. Thus for the first time we get an explanation of entropy, which dynamics alone failed to give, by means of statistical dynamics or probability.

Perhaps the most striking triumph of the statistical method has been its application to the theory of radiation from a hot body, which has been successfully worked out in the last decade, through the endeav-

ors of Lord Rayleigh, Wien, and particularly Max Planck. In order to explain the dependence of the distribution of energy in the spectrum upon the temperature of the radiating body Planck was led to consider the emission of energy from a large number of electrical oscillators, which from their power of absorption of energy may be also described as resonators. In order to find the entropy to be associated with these resonators by an application of Boltzmann's definition as a probability, and to define what is equally likely as to the amount of energy possessed by the individual resonators Planck found it necessary to assume that this amount of energy could not vary continuously, but must be an integral multiple of a certain very small amount which has been termed the elementary *quantum* of energy. The results of this quantum hypothesis of the atomic nature of energy has been to send a sort of earthquake shock through some of the foundations of physical theory, and we can not yet judge of the ultimate outcome. These matters were handled so thoroughly by my predecessor that I do not need to do more than mention their importance.

I have thus mentioned as the chief methods of physical investigation the method of pure dynamics, that of thermodynamics and that of the statistical method. I may add the method of which I have given an example, that of simple analogy, without the backing of any definite hypothesis. I have spoken of Carnot's successful use of this plan, also of Ohm's law as the analogy of Fourier's. A further example is found in the case of chemical reaction-velocities. Without making exact dynamical assumptions, in many cases it is sufficient to assume that the velocity of a reaction is proportional, like that of a pendulum moving in a highly resisting medium, to the distance yet to go to reach equilibrium, that is, to the amount of substance that has not yet reacted. We thus get an approach to completion proportional to an exponential function of the time. This exponential is of so frequent occurrence in all parts of nature that the reason for it is often overlooked and we see amusing instances of its rediscovery. It seems likely that this method of analogy, perhaps in this very example, may be of considerable application in biology. Suppose for instance, a portion of jelly inoculated by a needle with a certain bacillus. If the jelly is physically and chemically homogeneous the colony will grow at such a regular rate and with such a symmetrical form that it seems as if a differential equation could be formed, and the analogy with diffusion is very strong. If we could express biological forces or tendencies as we now can chemical ones there is no doubt that we could make long strides in this direction. What is now the outlook for our other methods applied to biology? Where we have to do with a distinctly physical phenomenon such, for instance, as in the propagation of the pulse-wave through the arteries, we may use the methods of pure dynamics. Or where we have to do with the conduction of the electrical current through the tissues we may use the known laws of electricity. But in connection with most of the phenomena of life we are far from having a sufficiently exact notion of the phenomena to apply dynamical principles. On the other hand, the method of thermodynamics may be of great use. No one, I suppose, doubts that the first law of thermodynamics is applicable to all physiological phenomena, both animal and vegetable. Whether it may be extended to mental phenomena is not so certain, and can not be settled until we are able to measure the amount of energy in mental processes. Certain experiments seem to show that we are near to this, and

yet I fancy that no psychologist will yet undertake to measure the relative amounts of energy involved in the composition of poetry, the translation from Greek or German, or the integration of a differential equation. Whether we believe with Mr. Arthur Balfour that "life and beauty and happiness are not measurable" or not, we are still far from having even proposed any units for their measurement.

The question whether the second law of thermodynamics is applicable to biological processes is an interesting one, and we may hope that it will some time be answered, but at present there seems to be great difficulty in defining entropy in connection with such processes. Until this at least can be done, we seem to be a long way from what seems to be the hope of many biologists to reduce the explanation of life to physics and chemistry. While I suppose that most of us believe, with Professor E. A. Schäfer, as stated in his British Association address of last year, that "the problems of life are essentially problems of matter; we can not conceive of life in the scientific sense as existing apart from matter. The phenomena of life are investigated, and can only be investigated, by the same methods as all other phenomena of matter, and the general results of such investigations tend to show that living beings are governed by laws identical with those which govern inanimate matter," while I say, most of us are willing to go so far, I presume that there are few physicists or chemists who will deny that there is probably some additional element involved in life, or who are willing to follow Professor Schäfer in his statement that "The combination of . . . these elements into a colloidal compound represents the chemical basis of life; and when the chemist succeeds in building up this compound it will without doubt be found to exhibit the phenomena which we are in the habit of associating with the term 'life.'" For if we can not answer the very direct questions that I have stated above how near are we to the position of certainty indicated by Professor Schäfer's words?

If the methods of dynamics and thermodynamics are not of present application in physiological processes, it is fair to suppose that they are even less so in connection with mental processes. That the statistical method is of value here however may be shown by consulting almost any psychological journal. A recent example is to the point. Many persons have the belief that they can tell when they are being stared at by a person whom they can not see. In order to test this subjects were placed under identical circumstances and an experimenter stared, or did not stare, as determined by the fall of a die, for a certain length of time, after which the subject reported on the result, without being informed of the true state of affairs. The guesses were then averaged, and the correct result having been arrived at in 50.2 per cent. of the trials, it was concluded that nothing more than pure chance had been in operation, and that the belief in the assumed ability is an error. What could be more like the examination of a physical phenomenon, and what more convincing? In the same manner we might examine the question of thought transference in general. The interest which the general public has in such investigations, and the desire that they be connected with physical phenomena, is illustrated by the incident of the publication, a few years ago, by a distinguished naturalist, of an obviously jocular account of "The Astral Camera Club of Alcalde," in which the formation of an actual image on the retina of a cat by thought transference was described with such particularity as to deceive so

many readers that an apology and explanation had to be published. What then shall we say of the attempt to push investigations into phenomena supposed not to originate in the world of matter, but in another world of whose existence we have as yet little knowledge, to put it mildly. Only that not only the general public is profoundly interested in the matter, but that eminent scientists, including astronomers, physicists and chemists of renown, have thought such investigations worth their attention, and have even declared themselves to have obtained results worthy of credence.

But how far are we justified in going in this direction? The objects of investigation in the physical sciences are manifold. In many cases we can control the phenomena to be observed, isolating them from disturbances, controlling the temperature, pressure, and other elements, and making the changes repeat at will. In other cases we can exercise no control, and yet the phenomena repeat themselves with periodic regularity, and can be observed at pleasure, as in the case of astronomical phenomena or the tides. In other cases the phenomena come at unknown times, irregularly, and we can observe them only by being prepared, as in the case of meteorological phenomena and earthquakes. But in all these cases there are definite phenomena, which we agree do exist, and which affect matter so as to be perceptible by instruments. But when we do not know whether phenomena exist or not how shall we investigate them? How easy it is for the layman to say, "We know that electromagnetic waves are transmitted through the ether, which we can not perceive by the senses, why should not waves be emitted by the brain, and be similarly transmitted through the ether?" Why indeed! We may answer him that even if we know nothing more of the ether than the speed of waves through it we know that extremely well, and that whether or not we know the mechanism of these waves (as I conceive we do) we at least know their differential equations, that is, the mode of their transmission. Moreover we have many instruments which are affected by these waves, whereas no one has ever managed, by means of thought waves, to affect the most sensitive instrument, whether torsion balance, quartz fiber, electrometer or galvanometer. When by taking thought, a mind in this world or the next, shall produce the smallest deflection in an instrument at a distance, then we shall be within the means of physical investigation. But, says the enthusiast, perhaps these waves, being not of physical but of mental origin, may be receivable not by physical, but only by mental apparatus, and may work only directly on the resonators of the brain. Very well, let us begin with the phenomena that we can control. It is easy to emit brain waves, if such there be. The method described above is then applicable. But if we are in the region of seismic mental waves, there is nothing to do but have our mental resonators always in adjustment and attuned. Then will come the difficulty of discriminating between "strays" and real receptions. How great this difficulty is is shown by the almost vanishingly small results of the societies for psychical research, so-called, and by the delusions from which reputable scientists have suffered. We may here mention the investigations on the celebrated Eusapia Paladino, who certainly secured good endorsements in Europe, but when brought here and examined by a committee including psychologists, physicists, and other detectives, was found to be explicable by purely physical hypotheses.

It is beyond my purpose to speak of the relations of science to religion and theol-

ogy, if indeed it has any such relations. But I can not resist recalling the scorn with which, in my boyhood, I remember hearing the minister describe Tyndall's famous proposed "prayer-test." I am free to say that I can not at present see why such a proposal should have created such a storm. If people actually believe in the existence of God, and that in addition he does grant requests addressed to him by persons of suitable character, what could be more suitable for decision by the statistical method than such a simple question? Fortunately times have changed, and the nature of prayer is now supposed to be quite otherwise, and to have its beneficent effect by reaction on the emitter, quite irrespective of its treatment at the receiving station. Nothing is more striking than the varying attitudes of scientists toward the subject of theology and religion, from the simple faith of a Faraday, Maxwell or Kelvin to the quite different attitude of a Tyndal, Huxley, or Haeckel. I take this to be due to the difficulty of defining the meaning of the theological terms, and to hazard the opinion that if we could define them even as well as we can entropy we should be found not to disagree profoundly. If it be true that "the undevout astronomer is mad," it is true because we admit that the chief effect of the pursuit of science is to give us a profound admiration for the workings of nature, together with the conviction that its methods are beautiful, definite and simple, and are capable of being understood by the human mind. If this is to say that they thus show evidence of having been designed by a great intelligence, like the human, but enormously more powerful, very well, but it is at this point that we begin to differ as to the meaning of our terms. The chief thing that the scientist should have learned is the possibility of his being mistaken, and the danger of denying in cases where he has no evidence. We must therefore conclude that while the methods of physical science have a continually widening field of application, we must advise him who asks the profoundly interesting question, "If a man die, shall he live again," to seek to answer it by other methods, *if he can.*

ARTHUR GORDON WEBSTER

THE TEACHING OF PHYSIOLOGY TO MEDICAL STUDENTS[1]

IN no way is the relative importance of physiology in the medical curriculum better attested than it is by the designation of "the Institutes of Medicine," under which it still appears in the catalogues of some of the older universities. Originating as a division of anatomy, physiology gradually assumed such importance in the medical curriculum as to necessitate the creation of an independent department, although for long the close relationship of the two subjects was maintained on account of the fact that conclusions regarding function had in large part to be inferred from an accurate knowledge of structure. It is for this reason that the study of the microscopic structure of the tissues was, and in some schools still is, assigned to the physiologist, and it is indeed only within comparatively recent years that there has been anything like a general change in the nature of the practical work which the student must do in his course in physiology.

As it now stands, physiology is generally defined as being the study of the phenomena of living things. "It deals with the process of life." It has nothing to do with the structure or morphology of dead things, although obviously a sound knowledge of this must be acquired before any attempt

[1] Address of the vice-president and chairman of Section K, Physiology and Experimental Medicine, Atlanta, Ga., December, 1913.

can be made to explain the functioning of the parts. Physiology, in short, must concern itself with an application of the known laws of physical and chemical science to the process of living in both plants and animals. It must, for example, endeavor to show whether the facts known to the chemist can be made available to explain the synthesis of the various constituents of plants, and the liberation of energy which follows the ingestion of these foodstuffs in animals; it must ascertain whether the movements of a muscle, the secretion of a gland, the transmission of a nerve impulse, are adequately accounted for by the known laws of physics, or whether there exists in living things some force that entirely alters or entirely obscures the physical process.

As thus defined, the science of physiology is obviously too wide in scope, and its ramifications too diversified, to make possible its inclusion as a subject in the medical curriculum. It must be delimited. For this purpose, the object aimed at is of course a knowledge of the functioning of the human animal, although in gaining this we must constantly endeavor to show, by observations on the lower animals, how the same general laws of function apply throughout the animal world. We must, above all things, treat the subject from a broad scientific point of view, not narrowing it down to a mere study of the complicated mechanism of the higher mammalia, but making it a general study of the essential nature of the life processes. Just in so far as the knowledge of physiology is sound will the practise of the physician be likely to be proficient.

For the medical student, therefore, physiology must serve as the connecting link between his pre-medical scientific studies and the clinical work which is to follow. It must be considered as the center to which the basic sciences converge, and from which diverge the various subjects that are related to the study of disease.

A knowledge of physics, chemistry and morphological biology constitutes the bedrock upon which the foundation of medical knowledge, represented by physiology, must be built, and it is only after the foundation is completed that it becomes possible to add the superstructure which is represented by pharmacology, experimental pathology, hygiene and medicine. Physiology bears to medicine much the same relationship that anatomy bears to surgery, for the physiologist of to-day is the physician of to-morrow, just as the anatomist of to-day is the surgeon of to-morrow.

The objects which must be kept in view in framing the course in physiology for medical students may therefore be stated as being: (1) a knowledge of the application of the known laws of physics and chemistry in living things; (2) a knowledge of the behavior of those life processes which can not at present be explained on a physico-chemical basis. To impart such knowledge, we must, in the first place, offer the student ample opportunity for the direct observation of the behavior of living things, so that his knowledge of physiology may rest upon a basis of personal observation rather than upon one of authority. The student must, above all things, be trained to be an investigator of the behavior of living things, and he must be constantly reminded that the observations which he makes on the normal animal are later to serve him as a standard with which to compare the behavior of the disturbed functions in disease. But practical courses alone will not suffice. They must be supplemented by didactic instruction of such a nature as to show the student how the facts which he himself gathers from direct observation can be linked together with one another and with those of other investiga-

tors, so as to form a connected account of the working of living things.

As to the actual pedagogical methods by which we are to fulfill these requirements, it will be convenient to consider, first, the practical, and secondly, the didactic instruction. A thorough training in the methods of accurate observation, as applied to living things, must be the first step in the physiology course, for even granted that the student may have graduated in experimental physics, it will still be necessary for him to become familiar with methods by which to control and simplify the variable and complicated factor that the existence of a living tissue now introduces into his experiment. The experiment in physics is one in which everything is more or less controllable, a result once obtained being readily repeated; whereas in physiology a disturbing element is constantly present, for the physiological properties of the living object, whose movement or other function we are examining, may alter from time to time on account of vital processes over which we may not have any known means of control.

There are, I believe, no physiological experiments more suitable for this preliminary teaching than those on the nerve-muscle preparation of the frog. The actual physiological truths which the student may learn by doing these experiments are certainly not of much importance, at least from the medical standpoint, but the facility in accurate experimentation which he thereby acquires, as well as the ability to use his results for inductively drawing general conclusions, is essential to his further progress.

There is one other feature of these experiments that is of great value from the pedagogical standpoint, namely, the possibility of grading them with regard to complexity. In a few weeks the experiment may pass from the recording on a stationary drum of the degree of muscular contraction resulting from electric stimuli of varying strengths to the determination of the rate of transmission of an impulse along a nerve. When the student has acquired such technical facility that he can repeatedly obtain the same results in this experiment, he may be considered as competent to proceed with the more complicated experiments necessary to elucidate the fundamental truths of physiology.

The experiments on nerve-muscle being thus largely of a preliminary nature, the time occupied by them should not be unduly prolonged; sixteen sessions of two hours each are certainly adequate.

From such work to the study of the heart-beat in frogs and turtles is a natural step, the experimental technique being much the same, but greater care being demanded in the handling of the object under investigation. But another element now enters into the work, for the conclusions which may be drawn from the experiment come to be of great importance in themselves, and fundamental physiological truths concerning the nature of the heart-beat begin to unfold themselves to the observing student. He begins to feel that he is building up his fund of physiological knowledge at first hand, and he gradually comes to take a real interest in finding out, by consultation with his text-books, to what extent his observations and conclusions conform with those that are generally accepted. To encourage the spirit of independent investigation, and to add interest to the work, it is advisable, after a sufficient number of experiments has been performed, to devote a session or so of the class to a symposium in which the results obtained in the experimental work are collated and their significance discussed. For this purpose, each student should be required to prepare in

essay form a review of his findings, which he may be called upon to read before the class, and which is then discussed by the other students, with the object of bringing out the variations that occur, and of emphasizing the chief conclusions.

The time allowed for these experiments should be about one half of that occupied by the preliminary nerve-muscle work.

The student may now proceed to the experimental work on mammals, beginning with such problems as the control of blood pressure, the mass movement of blood, and other circulatory problems, and then proceeding with those pertaining to the respiratory, digestive, excretory and nervous systems. It is in the conduction of this course that the greatest pedagogic skill is demanded, for the experiments must be most carefully chosen so that their results may bring to light fundamental principles, and so that there may not be unnecessary repetition. The animals employed must be deeply anesthetized, and there must be sufficient competent oversight to make certain that at no stage do any of them show the least signs of consciousness. The animals must of course be killed at the termination of the experiment.

The question is sometimes asked as to whether it is necessary for the efficient training of medical students that they should participate in mammalian experiments. In my judgment, the question is as absurd as if it concerned the practical training of engineers. To drive our locomotives we do not employ men who have merely learned the theory of engine construction; we demand such as have gradually acquired a practical knowledge by actual experience.

It is obviously unnecessary that every student of the class should perform each experiment by himself; groups, composed of four or five students, should be formed, care being taken that the particular duties of the various members are so controlled by rotation that each has an opportunity during the course of actually taking part in every technical detail of the experiment. There should also be a sufficiency of trained instructors so that there is approximately one of these for every two groups. Conducted in this way, the experiments come to assume in part the nature of demonstrations, but they are of immensely greater value than the older lecture-table demonstration, because each student, by being an active participator in the work, comes to take a very much greater interest in the bearing of the experiment, besides acquiring greater operative and technical facility, which will be invaluable to him in his subsequent clinical work.

There are some persons who would doubt the necessity of even demonstrating any mammalian experiments to medical students. They maintain that it is unnecessary to repeat observations that have already been satisfactorily made and recorded. But if this were true for physiology, it must obviously also be true for physics and chemistry. According to those persons, there could be no value in *any* practical work in the pre-medical sciences, which would mean that the student on entering the wards would be no more familiar with the methods which are at his disposal for the accurate investigation of disease than would be a student of theology or law. When we bear in mind, however, that a patient with a disturbed blood circulation is strictly the same from the pathological standpoint as an anesthetized animal with corresponding conditions produced experimentally, we see how unreasonable such a contention comes to be. Is it better to have the student learn how to control a breakdown in the circulation on the patient or on the anesthetized animal? It is pos-

sible in a comparatively brief period of time to make the student of physiology acquainted with the fundamental conditions which disturb the circulation of the blood, for he creates the disturbance at will; it would take years to show him the same things on patients, because the lesions must be taken at random as the cases present themselves in the clinic.

It has been asserted that the mammalian experiments at least should be merely demonstrated to the students and that they themselves should not be called upon to participate in them. It has been pointed out, for example, that the fact that two loads are of equal weight is no more convincingly demonstrated by one's actually placing the loads on the scale pans of the balance than by seeing this done by another person. But the difference between this and a physiological experiment is very very great, and furnishes the very reason for which the latter should be performed by the student himself. For this difference depends on the fact that we are dealing with living processes that may materially alter the result of the experiment unless they are adequately controlled; to learn how to control them is one of the most important things that the student of medicine can learn. It would go beyond the scope of this article to present other arguments for or against the inclusion of practical work on mammals in the physiology course, but there is one pedagogical criticism that sometimes is made against the experiments that should be taken notice of. This refers to the possibility that the student may lose sight of the object for which the experiment is being performed on account of the attention which he must give in order to overcome the technical difficulties which it involves. This is undoubtedly likely to be the case unless great care is taken to have each experiment preceded by a conference, and, after several have been performed, to have the results reported and discussed in seminars. It is true that it may not be possible for the student immediately to correlate and place their full meaning on the experimental results which he obtains, and for this reason the teacher should as frequently as possible refer to these results in illustration of the principles which he is endeavoring to unfold in the didactic courses. Ultimately, however, the observations which he himself has made come to furnish the mainstay of the student's physiological knowledge, and he uses them as the basis for his further development.

Eight to ten sessions of four hours each are required for the mammalian experiments, after which several sessions are occupied in making accurate observations on the physiological functions of normal men, one student in each group serving in turn as the subject of investigation. In recent years the methods available for studies of this nature have very materially multiplied, indeed have done so to such an extent that several of the fundamental principles of physiology can now be as adequately demonstrated on man as by experiments on the lower animals. This permits of a certain amount of displacement of the experiments on anesthetized animals, an object which, for various reasons, should always be kept in view.

Coming now to the place of the didactic instruction, it may in general be stated that this should be so arranged as to supplement the practical. The lecture and recitation are certainly as indispensable as the practical class, for in them the principles of physiology—the institutes of medicine—must be expounded in logical sequence, and, as has already been stated, the bearing of the experiments which the students themselves have performed must

be clearly explained. It is in the lecture that an enthusiasm for the work may be instilled in the student's mind, and it is important that too much weight be not placed on detail, but that every opportunity be taken to show the application of physiological truths in the practise of medicine. For details the student should be referred to the text-books. It is often stated as an objection to systematic lectures that the students come to depend upon the notes which they succeed in taking during them in preparing for their examinations. To offset this possible tendency, there are two other features of didactic instruction which are of great importance. The one is the recitation or quiz, and the other, the symposium. One recitation should follow every two lectures, and it should be conducted, not by the lecturer himself, but by an assistant, who, although using a general outline of the lectures as his basis for questions, does not keep to that alone, but reviews the subject from his own point of view. It is important that a record be kept of the manner in which the questions are answered by each student, for otherwise it is difficult to hold every member of the class to thorough preparation. Review quizzes covering the larger subdivisions of the subject, such as circulation, respiration, etc., are also of great value.

The symposia constitute a most important feature of the course. Besides the symposia on practical work, which have already been discussed, there should be literary symposia, or journal-club meetings, in which each student in turn is required to read before the class a short paper compiled from the literature on some theme which has been allotted to him by ballot. The themes must be carefully chosen, so as to permit of presentation within the short time which is available for such work, and so that there is adequate representation in the English and American journals. Some students may be given themes requiring consultation of German or French journals, but in our experience the college training in modern languages is inadequate for their extended use in this way.

A general discussion, by the members of the class and by the instructor, should follow the presentation of each paper, the paper and discussion together occupying twenty minutes, thus permitting three papers to be presented in an hour. It is advantageous so to group the papers that the themes discussed during each symposium are closely related, for by doing so a much greater interest is likely to be aroused than if non-related subjects are presented. To prepare, even for the simplest of themes, a well-balanced and comprehensive review of the literature that shall occupy but ten minutes to present, is certainly by no means an easy task, not alone for beginners, but it is impressed upon the students that the practise which they get in attempting to do it will be invaluable to them when later, as practitioners of medicine, they desire to present papers at medical societies. Appropriate reprints of original articles can be lent from the department library to the students, but besides this they should have free access to such general reviews as the Index Medicus or the Surgeon General's Catalogue, the use and value of which they thus come to appreciate. In order to stimulate their best efforts, we have found it advantageous to offer to submit the best two or three papers for publication to the editor of the local medical journal. There should not be much difficulty in most large medical centers of finding some editor who would be glad to find room in his journal, at least during the summer months, for the publication of well-written, up-to-date reviews on

current physiological literature. A copy of each theme is placed in the department library, and its merit is taken into consideration in determining the final grade of the student.

Finally, at the very beginning of the physiological course there should be several lectures on general physiology, and at occasional periods during it there should be demonstrations by the instructors of more complicated experiments, which it would be impossible for the students themselves to perform.

Much has been written in recent times regarding the relationship of biochemistry to physiology, some believing that each subject should be assigned, like chemistry and physics, to separate departments, whereas others maintain that since physiology proper is the application of both chemistry and physics to the process of living, it should be taught by one who is more or less versed in both of these contributory sciences. In the present connection, our judgment is somewhat simplified by the fact that the question refers solely to the physiological training of medical students, to whom physiology must be taught because it is to serve as the foundation upon which is to be erected their subsequent knowledge of clinical medicine. It must be taught not in dissociated parts, but as an integrated assemblage of all the facts and observations from which its generalizations are induced. It does not matter very much whether the head of the department of physiology is primarily a chemist or a physicist. He should, however, be sufficiently familiar with both sciences to make it possible for him to teach the principles of physiology from both points of view, leaving detailed and practical instruction to associates who are specially trained in the purely experimental or in the purely chemical aspects of the subject. By such an arrangement, the professor of physiology in the medical school might be either an experimental or a chemical man, and his chief assistant would be especially qualified in whichever branch he himself was not so. Above all things, however, we believe that the two subjects should be taught together so that their interdependence may be constantly insisted upon.

Optional courses in special subjects, given by various members of the physiological staff, offer an important means for making the students cognizant of the nature of the research work which is going on in the physiological world. Although such courses are likely to be attended by the best students only, the class as a whole will come to realize that the department is alive and up-to-date, and that what they learn in the general course can represent but the very fundamentals of their science. The experience in teaching which the instructors gain by giving these optional courses is a further important reason for giving them. There is a growing opinion, and rightly so, we believe, that the experienced head man in the department should expend his energies in teaching the fundamentals of his science, and that he should delegate to his junior associates the conduction of advanced classes. This does not mean that he himself should not offer some advanced course in a subject in which he is specially interested and proficient, but it does mean that to leave to immature and undeveloped assistants the teaching of the fundamentals of the subject as a whole is pedagogically unsound, and is certain to produce a class of students that are unequally trained, and, besides, have a low estimate of the value of the course.

The object of a course in physiology being to train the student in the exercise of his faculties, rather than to jam his memory full of the accumulated truths that fill its

archives, it is important that he begin under the instruction of one who by experience is able to present the sequence of evidence which leads up to the establishment of even the most elementary truths of his science. If the scientific attitude be acquired at the beginning, the student's mind is prepared for the constant acquisition of new knowledge, which he comes to be able to assimilate with less effort, and with immensely greater profit to himself.

An unfortunate feature of every course is the necessity of examination. The necessity exists for two reasons: 1. To offer a disciplinary method by which each student is compelled to study the subject. 2. To ascertain whether he has mastered his subject sufficiently. It is not the purpose in the present paper to enter in any detail into this much-discussed pedagogical problem. It is certain, however, that in no other respect is the teaching of such a subject as physiology likely to be rendered inefficient and unpractical more than by too much examination. As we have stated before, a record of the general behavior of each student in the quizzes, in the practical courses, and in the symposia, should be kept, so as to serve as the main basis upon which his proficiency is determined, the finer grading being based on a comprehensive final examination, which should be partly oral and partly written in nature. In this final examination opportunity would be offered to sort out those students whose standing, as judged from the class records, is uncertain.

Occasional written "tests" are no doubt of some use in permitting the students to measure their standing, and in supplying them with a motive for reviewing their work. But it is a mistake to offer these tests too frequently, for it makes the student consider the obtaining of high grades as the main aim and object of his studies. By his success in getting high grades, the crammer, who merely memorizes what he hears or reads, comes to be considered as the really successful student, whereas the thinker who accepts nothing until he understands it is discouraged because he can not keep the pace.

And finally as to the future of the physiological student, how is his fund of knowledge to help him most in becoming an efficient diagnostician and therapeutist? The answer is by keeping him in constant touch with physiology during the time that he is acquiring his clinical knowledge. To accomplish this is, however, a most difficult problem, for it requires that the teacher of clinical medicine shall himself be well informed in the modern teachings of physiology, a qualification which unfortunately but few of our clinical experts possess, or which they make any effort to acquire. There has no doubt been a great change in the nature of the teaching of clinical medicine during recent years. The old-fashioned empirical dogmatism is gradually giving way to more logical and scientific methods, but even in our best-manned school clinics, there yet remain many who by their attitude towards such a science as physiology and towards the newer methods of refined diagnosis, which depend on the application in bedside work of physiological methods, make it very difficult to realize the above ideal. Naturally enough the unthinking student prefers to be taught cut-and-dry systems of diagnosis and treatment. In his textbooks of medicine, he finds tabulated groupings of symptoms by which he may distinguish one disease from another, and he expects that, having learned how to diagnose, all he has to do is to learn the prescribed treatment for the disease. By learning his medicine in such a manner—and of course it is in such a way that he

learns it when he attends so-called quiz classes in medicine—he is very likely to lose all of his scientific attitude towards the management of disease. He comes to think of diagnosis as being nothing more than an endeavor to find the text-book name for the disease under which the grouping of symptoms which he elicits happens to fall, and he loses sight of the fact that the symptoms are the outcome of disturbed function or functions, and that they may vary very much indeed in different individuals, according to the degree of physiological disturbance which the lesion creates. He becomes a student of symptoms rather than an investigator of the conditions which are their cause. After all, text-books of medicine are intended only as rough guides for the classification of disease, and it is fatal to efficiency in medical training if this fact is not constantly borne home on the student. He must be taught to study and treat each patient as an individual problem, and just as he has learned in the practical course in physiology that the same experimental condition may lead to different reactions in different animals, so must he expect to find among different patients the same want of uniformity in the symptoms which are produced by the same lesion. The student must be constantly reminded that the practise of medicine is in its merest infancy, and that its growth depends almost entirely on the degree to which it will be possible to apply the accurate methods of physiology and experimental medicine to its investigation. In the past, the development of knowledge of the disease of the circulating system, for example, has depended upon the use of the simple methods of auscultation and percussion; at the present it is bound up with the use of the electrocardiogram, the polysphygmogram and the skiagram, and in the future it will undoubtedly be largely dependent upon methods which will be born and cradled in the physiological laboratories. Every man trained in the right atmosphere becomes a potential contributor to the advancement of clinical knowledge.

In order to carry out these ideals in the teaching of medicine, it is necessary to provide courses such as experimental pharmacology and so-called experimental medicine, in which the more purely physiological experiment is modified so as to show how its results can be used in the investigation of disease. By giving pharmacology in the third year of the medical course, and experimental medicine in the fourth, the difficulty that the student will disregard the scientific aspect of medical practise is much lessened.

In this discussion it should be pointed out that the term physiology is employed in the broad sense under which it was defined at the outset, that is: it includes the physical, the purely biological and the chemical phenomena of life.

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ACCIDENTS IN COAL MINES

THE lack of comparable and accurate statistics of coal-mine accidents in the United States has led the Bureau of Mines to collect such data, and the results of these investigations have been compiled by Mr. F. W. Horton, in Bulletin No. 69, entitled "Coal Mine Accidents in the United States and Foreign Countries," which has just been issued. This report shows that during 1912, 2,360 men were killed in the coal mines in the United States as compared with 2,719 for 1911, and that the fatality rate was lowered from 3.73 in 1911, to 3.15 per 1,000 men employed in 1912. The report contains statistical information concerning the production, the number of men employed and the number of men killed in each state since 1896. From 1896 to 1907 the number of men

killed per 1,000 employed gradually increased with only slight fluctuation; the number killed per 1,000,000 short tons also increased, but the rate fluctuated over a wider range.

During this twelve-year period through 1907, the increase in the death rate was accompanied by an enormous increase in the production of coal. In 1896 the output was 191,986,000 tons, and in 1907 it was 480,363,000 tons, an increase of over 150 per cent. In 1896 each man employed produced 2.64 tons coal per day, whereas in 1907 the daily production of each man was 3.06 tons, an increase of 16 per cent. Since 1907 there has been a marked decrease in the number of fatalities at the coal mines.

This general improvement has been brought about by a combination of causes, the principal one of which has been more efficient and effective mine inspection on the part of the state mining departments and the state mine inspectors throughout the country, supplemented by greater care on the part of both operators and the miners. The investigative and educational work of the Bureau of Mines has kept both the operator and the miner alive to the various dangers connected with coal mining, and has shown what precautions should be taken to avoid these dangers. As a result of these educational features, mining companies are organizing safety committees; providing emergency hospitals, training men in first aid and rescue work, so that in case of a disaster they are equipped to cope with any ordinary accident.

The fatality rates in a number of foreign countries covering a period of ten years, 1901 to 1910 inclusive, are as follows:

Great Britain, 1.36 per 1,000 men employed; Germany, 2.11; France, 1.69; Belgium, 1.02; Japan, 2.92; Austria, 1.04; India, 0.96; New South Wales, 1.74; Nova Scotia, 2.65, while the rate for the United States was 3.74. The low fatality rates in the foreign countries may be accounted for largely by reason of the fact that coal-mine inspection has been in operation much longer than in the United States. In Great Britain the coal mine accident statistics have been collected, published and studied since 1851; France, 1853; Austria, 1875; Germany, 1852; and Belgium, 1831.

A chronological list of the more disastrous coal-mine accidents in the United States shows that 275 accidents have occurred since 1839, in which five or more men were killed at one time, representing a total of 6,777 fatalities. Of these accidents there were 135 that killed from five to nine men each, a total of 859; eighty-two that killed from ten to twenty-four men each, a total of 1,237; twenty-five that killed from twenty-five to forty-nine men each, a total of 870; eighteen that killed from fifty to ninety-nine men each, a total of 1,221; eleven that killed from 100 to 199 men each, a total of 1,534; three that killed from 200 to 299 men each, a total of 695, and one that killed 361 men.

Of these larger disasters gas and coal-dust explosions caused 183 accidents and 5,111 deaths, or over three fourths of the total number of men killed. The next greatest number of deaths were from mine fires, which caused the loss of 1,082 lives, or over fifteen per cent. of the total number killed, by thirty-three separate accidents. It may thus be seen that accidents from gas and coal-dust explosions and mine fires account for more than ninety per cent. of the total number of men killed in these large accidents, although falls of roof, pillars and walls claim nearly fifty per cent. of the total fatalities.

THE RADIUM RESOURCES OF THE UNITED STATES

Secretary Lane proposes to withdraw all lands of the public domain suspected of containing radium, that their deposits may be secured for the public good and not become the subject of private speculation. Mr. Lane has outlined his plan in a letter to Chairman Foster of the House Mines Committee, urging immediate passage of a joint congressional resolution to empower President Wilson to make the withdrawals. Investigations of the Geological Survey have located public lands believed to contain the substance now so invaluable in medicine. By the terms of the proposed resolution the Secretary of the In-

terior would be authorized "to conduct explorations and researches with a view to determining the practicability of developing from such ores a supply of radium and to provide for the mining and treatment of radium-bearing ores in such manner as would best secure a supply of radium for the use of the government of the United States and the hospitals of this country."

Secretary Lane points out that there are only two grams of radium at present in the United States. It is valued at $120,000 a gram. All has been procured from Europe. "Three fourths of the radium produced in the world during the year 1912," says Secretary Lane, "came from American ores, yet we have, up to this time, taken no steps whatever to preserve for our own people this invaluable metal, and our physicians and hospitals are dependent upon European laboratories for such supply as they can procure, and are subject to whatever monopoly charge the European laboratories demand for their product."

In view of the use of radium in the treatment of cancer and the difficulty now experienced in obtaining a supply of it, Secretary Lane says, that as one person in every ten in this country more than fifty years of age suffers from cancer, "it is difficult to overestimate the necessity of securing immediately as large a supply as possible of this mysterious remedy." Continuing, the secretary says: "Radium is found in ores carrying uranium and vanadium, which are used extensively in the arts, and processes by which it is extracted are secret. A process has been invented by the chemists in our Bureau of Mines which promises, from the laboratory experiments thus far made, to be successful. Under the endowment of two Americans, a building is now being erected in Denver (which, with its equipment, will be opened for work in the coming February), in which an effort will be made to prove the commercial possibility of this American process. If successful, this process will be given to the world, and all of the radium secured over and above a small minimum will be the property of the United States, and will be put into the hands of the United States Public Health Service for public use. Under all these circumstances it seems to me that the only prudent course that the United States can follow is to withdraw such of its lands as are supposed to contain radium from public entry. This will guard against these lands being taken up by those who would not put them to their highest and most beneficial use. It would be inhuman to deprive other nations of access to our radium deposits if they alone were masters of the secret by which this mineral could be secured, and it is believed that there is a sufficient amount of carnotite and pitchblend already in private ownership in this country to permit of continued European experimentation and production. The people of the United States, however, should be entitled to protection against the exhaustion of this resource and its exclusive control by the scientists of other lands."

SCIENTIFIC NOTES AND NEWS

IT is proposed to place a suitable memorial of the late Alfred Russel Wallace in Westminster Abbey. It is also proposed to present a statue or bust to the British Museum of Natural History and a portrait to the Royal Society. Contributions to the Alfred Russel Wallace Memorial Fund may be sent to the Union of London and Smith Bank, Holborn Circus, London, E. C.

LORD RAYLEIGH will unveil a tablet to the memory of Lord Lister at King's College, London, on January 14. The ceremony will be followed by the inaugural lecture of the newly appointed professor of physics, Professor O. W. Richardson, F.R.S., recently of Princeton University, who will take as his subject "The Discharge of Electricity from Hot Bodies." Lord Rayleigh will also preside at this lecture.

SIR ARCHIBALD GEIKIE, the distinguished British geologist, has been appointed a member of the Order of Merit, filling the vacancy caused by the death of Alfred Russel Wallace.

OTHER New Year's honors in Great Britain include a viscountcy conferred on Mr. James

Bryce, recently British ambassador at Washington.

The National Geographical Society has awarded a medal in honor of the late Professor Franklin Hiram King for his work on Chinese agriculture.

Colonel Gorgas, M.D., chief sanitary officer of the Panama Canal, has been elected an honorary fellow of the Royal Sanitary Institute, London.

The executive committee of the board of trustees of Cornell University has made the following expression of its feeling with respect to the resignation of Professor J. H. Comstock:

> In accepting the foregoing resignation the trustees congratulate Professor Comstock on his long, honorable and fruitful service to Cornell University, with which as student and teacher he has been associated almost without interruption since he matriculated as a freshman, and they bear grateful testimony to his success in teaching and in inspiring students and also in scientific investigation, for the continuance of which they trust his health and energy may be preserved for many years to come to the honor of his alma mater and the advancement of truth and knowledge.

After accepting the resignation of Professor Charles DeGarmo, the committee adopted the following minute:

> Dr. DeGarmo came to Cornell after twenty-five years' labor as teacher and administrator in school, college and university. Under his guidance the department of education was reorganized and has been a large factor in the preparation of many students for usefulness. During his years of service to Cornell he has wielded a widespread influence in the country through his writings, his addresses to gatherings of school men, his helpfulness to those charged with school administration. In the university he has inspired others by his teaching and even more by the gentle nobility of his character, and by his steadfast devotion to the highest standards of life and work.

Professor Simonin, of the Paris Observatory, Professor Abraham, of the University of Paris, and Captain Carrier, of the French army, the three savants cooperating with a similar party of Americans in determining, with the assistance of radio signals, the difference of longitude between Washington and Paris, recently delivered short addresses before an audience comprising the Naval Observatory staff and representatives drawn from the naval and scientific circles of Washington.

At the annual meeting of the American Ornithologists' Union in November last it was decided to increase the membership of the Committee on Classification and Nomenclature from seven to eleven with the object of having it organize as two subcommittees, one of four members to consider matters of nomenclature, the other of seven members, to cover systematic and geographic questions, especially the acceptance or rejection of proposed new forms. The president, Dr. Frank M. Chapman, has reappointed the old committee, consisting of J. A. Allen, William Brewster, Jonathan Dwight, Jr., C. Hart Merriam, Charles W. Richmond, Robert Ridgway and Witmer Stone; and as the four additional members he has named Joseph Grinnell, E. W. Nelson, Harry C. Oberholser and T. S. Palmer.

Mr. G. W. Lamplugh, F.R.S., has been promoted to be assistant director of the Geological Survey of Great Britain, and Mr. T. C. Cantrill to be district geologist.

W. S. Valiant, for twenty years assistant in the geological museum of Rutgers College, has been appointed curator. Professor J. Volney Lewis, formerly designated curator, has been made director.

The autumn series of public lectures, given at Washington University, St. Louis, came to a close with an address by Dr. Eugene L. Opie on "Modern Tendencies in Medicine."

The Friday evening meetings of the Royal Institution, London, will be resumed on January 23, when Sir James Dewar will speak on the coming of age of the vacuum flask. Among the lectures announced is one on the mechanics of muscular effort, by Mr. H. S. Hele-Shaw, F.R.S., and another on the production of neon and helium by electric discharge, by Professor Norman Collie, F.R.S. On February 20 Professor Arthur Keith, conservator of the Museum of the Royal College of Surgeons of England, will relate the results of an

anthropological study of the busts and portraits of Shakespeare and Burns.

THE library of the late Professor Ernest Ziegler, formerly professor of pathology at the University of Freiburg, purchased for the University of Pittsburgh by Mr. Richard Beatty Mellen was formally presented to the university at a meeting held in the University Club, Pittsburgh, December 5. The addresses of the evening were given by Dr. William H. Welch, Baltimore, and Mr. Harrison W. Carver, Pittsburgh.

DR. S. WEIR MITCHELL, distinguished as a man of science, as a man of letters and as a physician, died at his home in Philadelphia, on January 7, at the age of nearly eighty-four years.

DR. SETH CARLO CHANDLER, the distinguished astronomer, at one time assistant to Dr. B. A. Gould, aid in the U. S. Coast Survey and in the Harvard College Observatory, since 1885 engaged in private investigation, died on January 31, at the age of sixty-seven years.

DR. FREDERICK CARL BUSCH, for some years professor of physiology at the University of Buffalo, recently engaged in cancer research, died from that disease on January 3, aged forty years.

HIRAM JOHN MESSENGER, Ph.D. (Cornell), for the last fifteen years the actuary of the Travelers Insurance Company, at one time associate professor of mathematics in New York University, author of publications on social statistics, died at his home in Hartford, Conn., on December 15.

BY the will of the late Mr. Arnold Friedlander, an English merchant, $25,000 is left for a cancer research fund.

THE Ecuadorean government has approved the contract with a London firm for the sanitation of Guayaquil. The question of cleaning up Guayaquil has been under consideration for a long time. Bubonic plague and yellow fever have been prevalent there, and the proper sanitation of the port was made the subject of an investigation by Colonel William C. Gorgas, head of the sanitary work in the Panama Canal zone. The installation of a proper sanitary system has been made imperative by the early opening of the Panama Canal. It is understood that the cost of the work will approximate $10,000,000.

UNIVERSITY AND EDUCATIONAL NEWS

THE movement for the establishment of a national university in Washington on the plan indorsed by the National Association of State Universities is taking form, and President James, of the University of Illinois, has, it is understood, commenced the preparation of a bill soon to be submitted to President Wilson for his approval and afterwards to be introduced in both houses of Congress. The bill will carry a preliminary appropriation of $500,000 toward the establishment of a university to be under the control of a board appointed by the president of the United States. It will propose an advisory board made up of one delegate from each state to frame the policy of the institution.

THE will of the late Seth K. Sweetser, of Brookline, Mass., makes public bequests amounting to $137,000, including $25,000 to the Massachusetts Institute of Technology.

ANNOUNCEMENT is made that the Cleveland City Hospital and the school of medicine of Western Reserve University are to be affiliated. The agreement which will be entered into by the city and the university will provide that all members of the visiting staff of the City Hospital shall be nominated by the trustees of Western Reserve University upon recommendation by the faculty of the school of medicine. The visiting staff will have absolute authority over the professional treatment of all patients of the hospital. The director of public welfare will be the administrative head of the hospital. The university will have all teaching and research privileges.

TWELVE colleges, hospitals and charitable institutions of Minnesota, nine of them in Minneapolis, are the recipients of New Year's gifts aggregating $230,000 from David D. Stewart, of St. Albans, Me., who inherited the

estate of the late Levi M. Stewart, of Minneapolis. Mr. Stewart in the last year has given away $630,000, practically half of the estate that was left him. About $400,000 went to churches, colleges and charitable institutions in Maine.

By the action of a New Haven court Yale University is adjudged not entitled to a legacy of $700,000. The money was devised by Mrs. Henry O. Hotchkiss, who died last year. The court rules that the will is void because Mrs. Hotchkiss did not get for herself complete and ultimate control of the money.

Dr. John Huston Finley was installed president of the University of the State of New York and commissioner of education on January 2. The inaugural address by Dr. Finley was given in the afternoon session. Other speakers included St. Clair McKelway, chancellor of the university; Nicholas Murray Butler, president of Columbia University, and Calvin N. Kendall, commissioner of education of New Jersey. The program for the evening included addresses by Governor Glynn, Franklin K. Lane, secretary of the interior; Charles W. Eliot, president emeritus of Harvard University, and Jean J. Jusserand, ambassador from France.

The American Political Science Association at its Washington meeting last week adopted a resolution providing for the appointment of a committee of three "to examine and report upon the present situation in American educational institutions as to liberty of thought, freedom of speech and security of tenure for teachers of political science." The committee was authorized to cooperate with similar bodies of other societies of the social sciences.

The examiners for the Shaw Fellowship open to graduates in philosophy of the four Scottish universities have recommended that it be awarded to Mr. G. A. Johnston, of Glasgow. It is of the annual value of about £160, and is tenable for five years.

Mr. A. E. Mortimer-Woolf has been appointed demonstrator in the department of anatomy at King's College, London.

Mr. George Senter, D.Sc. (Lond.), Ph.D. (Leipzig), reader in chemistry in the University of London and lecturer in chemistry at St. Mary's Medical School, has been appointed head of the department of chemistry at Birkbeck College, London, in succession to Dr. Alexander McKenzie, who has been elected to the chair of chemistry at University College, Dundee (University of St. Andrews).

DISCUSSION AND CORRESPONDENCE

A MODERN TEXT-BOOK OF GEOLOGY—AND EVOLUTION

Time, after all, is a matter of relativity for most of us. To-day, under circumstances, may really be yesterday. A little scientific book of the time of the middle of last century—a few years, say, after the publication of Darwin's "Origin"—has just come under my eyes. But it could not have come much before because its title page bears the imprint, "Quebec, 1913."

It is a little text-book (in French) of geology: "Abrégé de Géologie, par L'Abbe V.-A. Huard, A.M., Directeur du Naturaliste Canadien, Conservateur du Musée de l'Instruction Publique, et Entomologiste officiel de la Province de Quebec."

It is one of a series of similar books by the same author (zoology, botany, mineralogy, geology) which form a "Cours abrégé d'histoire naturelle, à l'usage des maisons d'education." It is, in other words, an introduction and guide to science for the rising generation of French Canadians.

It comprises six chapters about the earth's crust, the agents that modify it and the fossils that lie in it; and a seventh divided into two articles: "Art. 1, L'histoire primitive du genre humain; Art. 2, Ce quil faut penser du transformisme." It is this last chapter particularly that seizes one's attention.

The first paragraph of the first article concerns the "age of the human species." It is as follows:

"The infallible authority of the Church—[have I neglected to mention that the reverse

of the title-page of this text-book for secondary schools bears the imprint, "*Nihil obstat*," followed by the signature of the "*censor designatus*" and the *imprimatur* of the bishop administrator of Quebec?]—the infallible authority of the Church has made no definite determination as to the date when God created man, nor, by consequence, when man commenced to exist upon earth. There is a chronology in the Holy Books written under the inspiration of God, but in addition to the fact that it must be admitted that in the work of the ancient copyists extending over long periods of time the figures of this Biblical chronology may have been considerably altered, we may believe also that the sacred writer has not pretended to any completeness of genealogy of the patriarchs. Thus from the evidence of Revelation there is no absolute statement to be made relative to the existence of man on the earth; moreover, this is a question that interests neither dogma nor morals."

In two succeeding paragraphs the teacher states that geological evidence shows that man did not exist in the Tertiary epoch. The geological indications are that the creation of man dates from the end of the first period of the Quaternary. "One may add that there is to-day a tendency to believe that the human species has existed for 9,000 or 10,000 years; but this is only an opinion more or less probable that each is free to accept or reject for himself."

The second part of the chapter takes up, as I have already indicated, the subject of evolution. It begins with a recognition and demonstration of the unusually favorable condition of the infants of Quebec as regards science.

"With us," writes the good Abbe, "the little child when it has well learned its catechism is sure of the solution of the most grave problems which can disturb the human mind; it is in possession of the truth on the most important of questions. It knows, for example, the existence of God, that is to say the existence of the eternal Being whose perfectness and power are infinite. It knows that God has created, that is to say produced by an act of His will, the whole visible and invisible universe; and as regards our earth, it knows that God has created all the kinds, mineral, vegetable and animal that are found on it. The science of this little child is then already immense, and it is certain."

In painful contrast to this, the teacher finds that "in other lands there are unfortunately men who pass for savants, who ignore or refuse to admit and even combat these truths which rest not alone upon revealed religion, but also upon philosophy and upon the natural sciences where they are impartially questioned and legitimately understood. These men attribute all the development of the world, organic and inorganic, solely to the forces of nature, and they do this either to eliminate any necessity of intervention in this development by God or to discredit the Church which He has established." However, our author admits in a footnote[1] that not all evolutionists have such perfidious intentions, these others being engaged in following the chorus-masters of evolution simply by their lack of scientific knowledge and capacity for reflection, or because they wish to be believed to be in the scientific swim, *à la mode*.

M. Huard then proceeds to a brief setting forth of the actual hypothesis—the absurd hypothesis—of transformism, and of the trivial and thoroughly exploded alleged factors of this evolution: namely, natural selection, the influence of the use of organs, and the influence of the environment. "It is necessary to add that these famous principles of the evolutional hypothesis have no longer many partisans to-day, because the actual facts have proved their unreality. It is well, however, to know them at least by name, because of the historic interest which still attaches to them."

M. Huard then offers a series of scientific criticisms of evolution which are sufficient in themselves to make untenable any belief in it, without making appeal at all to those other

[1] "Il ne manque pas, assurément, d'évolutionnistes qui n'ont pas ces intentions perfides, et qui ne se sont engagés à la suite des coryphées du transformisme que par défaut de science ou de réflexion, ou pour suivre ce qu'ils croient être le courant scientifique du jour."

presumably even more convincing "*motifs tres graves*" that the theologians and philosophers have for disproving the hypothesis of the evolutionists.

These objections to evolution, "drawn exclusively from the domain of science," are as follows (quoted unabridged and unmutilated):

"1. The great objection that can be made, *a priori*, to evolution, and one which should make unnecessary all discussion, is that it is impossible to cite in its favor a single fact, well determined and legitimately interpreted, which shows that a single species has certainly evolved into another species. It is evident that a single fact of this kind would be sufficient, if not to establish solidly the hypothesis of evolution, at least to break much of the force and worth of the arguments of the adversaries of the hypothesis.

"2. As regards man himself, one has gone so far as to attribute to him for ancestor, the monkey, which by successive betterments should have finally become the human creature. Only, one can give no proof of this transformation; one knows none of the intermediate beings which should have formed an uninterrupted series between the monkey and man. Let us add that whether we consider the cranial development, or the anatomical structure, there are very great differences between man and even the most perfectly constituted monkey. It is the intellectual faculties, above all, which offer no ground of comparison between man and monkeys. It is necessary then to admit, from the scientific point of view, the direct creation of man by God.

"3. Just as the human being has remained the same from the beginning, so also have the animal and plant kinds remained the same, as proved by the study of fossils of all the geological epochs. There is not the least proof that a single species can, in however long a time, become another species. There have been, without doubt, both with man and with animals and plants, changes due to climate, nutrition, the soil, etc.; these changes have given rise to *varieties* more or less stable, within the species, but never to new species. The trilobites, for example, whose history can be followed in the geological strata up to their very end, since they did not persist beyond the Tertiary epoch, have offered in only a dozen of their three or four hundred species, no more than slight variations, which were not even completely maintained by their descendants.

"Evolution, *understood in a very restricted sense*, can then show us new varieties that only culture or other causes can produce; but there its power ceases, as experiment has demonstrated.

"4. Paleontology testifies that species have not appeared, from the beginning, as a series of successive, ever better stages, but they have appeared suddenly and without relation to the species existing before. And they have appeared all at once in all their relative perfection.

"5. If evolution had, as it is claimed, produced the perfecting of species, the last come among organisms would be the most perfect. Now, the study of fossils proves that the contrary is often true. For example, the most ancient fishes, the first sea-urchins, the oldest plants, the Carboniferous amphibia, were more perfect than the fishes, sea-urchins, amphibia and plants of to-day.

"6. It is not superfluous to add to what has preceded that since the beginning of historic time there has been recorded no sign of the passing of one species into another, neither among the plants nor animals.

"The conclusions to draw from all this are: (1) that the fixity of species is a scientific truth clearly and solidly established; (2) that God himself, author of all that exists outside of himself, has directly created man and all the animal and plant species."

To add anything to this is to produce the anti-climax. Yet it must be noted that Abbe Huard's text-book has not gone wholly without criticism in French Canada. In *Le Pays*, of Montreal, a writer took some exception to the Abbe's position on evolution. *Le Pays* was reprimanded by the Archbishops of Montreal and Quebec and the reading of the journal interdicted. In *Le Naturaliste Canadien* (October, 1913) (his own paper) the Abbe Huard refers appreciatively to the incident, and mentions

that the single one of the pro-transformism arguments of the writer in *Le Pays* which remains in his memory is, that the best geologists of the United States believe in evolution. The Abbe justly remarks that the argument does not seem to him overwhelming. For, he adds, they and even most geologists of the English language and protestant faith are partisans of evolution because of their lack of philosophic and religious instruction.

V. L. K.

STANFORD UNIVERSITY, CAL.

A SIMPLE APPARATUS FOR ILLUSTRATING PHOTOSYNTHESIS

THE use of experiments, illustrating the various physiological processes in plants, are coming more and more into use in connection with the teaching of elementary botany in the secondary schools. Unfortunately the funds available for the purchase of apparatus are so limited in many of these schools that the teacher has to resort to the method of making the various experiments before the class, while the students make notes on the results, etc., to be written up in their laboratory notebooks later. Such a method as this is very good if nothing better is available, but of course the best results are obtained by the students themselves making as many of the experiments as possible. I devised the following simple apparatus for illustrating the necessity of carbon dioxide and light in photosynthesis. Since it has worked with success, I thought that a short account of it might be justified.

Ordinary bottle corks, about 2 cm. in diameter, and 1 cm. thick, should each have a hole cut through the flat side with a large cork borer. The holes should be about 1.5 cm. in diameter. Through one side of each of the cork rings thus formed, a small hole should be made for ventilating purposes. The large hole in each ring should now be covered on one side by cementing on a small piece of mica, or, if mica is not available, small round cover glasses will do, but will require more careful handling subsequently as the glass breaks more easily than the mica. A sufficient number of these discs should be made to provide each student with six of them, two of which should be blackened to exclude the light.

In order to perform the experiment successfully a bright day should be selected, and only such plants should be used as have the stomata on the lower sides of the leaves. Plants with the stomata on both surfaces can be used, however, provided that the upper surfaces of the leaves used in the experiment are greased with cocoa butter or vaseline. The plant should be left in the dark long enough for the starch to be removed from the leaves before the experiment is started.

The cork discs, which have just been described, should be pinned to the leaves in pairs, one on the upper surface, and another on the lower surface opposite it so as to form small enclosed chambers in each instance. The blackened discs should constitute one pair so as to form a dark chamber. In order to exclude carbon dioxide the lower chamber of one of the other pairs of discs should contain small lumps of soda-lime, while the third pair will serve as a control to show that the presence of the discs themselves does not interfere with starch formation.

After the plant has stood in the sunlight for a few hours the leaves upon which the experiment is made should be removed, boiled in water, left in alcohol for a time and tested for starch in the usual way. If the experiment has been properly conducted, no starch will be present where carbon dioxide and light have been excluded, but it will be present in abundance under the discs used as a control. Groups of from two to four students can work together if the class is large and the number of discs limited.

It has been found that rather large-leaved plants with stiff petioles are better for use, in which case one leaf is sufficient for the three sets of discs. If plants with delicate leaves are used the discs can be supported by bending short lengths of soft iron wire at right angles near one end of each, and inserting the bent end in the side of one of the discs in each pair, while the other end of the wire is stuck into the soil below.

ALBAN STEWART

UNIVERSITY OF WISCONSIN

EXPEDITION TO THE AMAZON

To the Editor of Science: Mr. Algot Lange, of New York, writes from the headwaters of the Cairary and Mojŭ in the Amazon region, Brazil, as follows:

I took my 6-man canoe above 5 long and dangerous rapids at the headwaters of the Mojŭ and Cairary rivers and after 15 days search I got in touch with this virgin tribe. I use the term virgin because, as I sit here alone (the only non-savage man) among about 50 Indians, I see how absolutely untouched and unspoiled this tribe is. They use stone axes and I am now showing them the use of steel axes.

Their language is not Tupi. What stock can it be, Arowak or Carib? They are agriculturists and have felled about 30 acres of jungle, with their stone axes—it looks to me as if they must have chewed the trunks. They grow cotton.

The men go nude absolutely. The women wear a narrow, colored loin-cloth.

I am received very hospitably. I am here in commission by the government [of Brazil] to look up the indigenous tribes and ascertain their different social and economic possibilities and their most urgent needs and the best way of entering into friendly relationship.

Some of the men have almost Hebraic features with brown eyes. They are tall and muscular in build. They have great skill with the bow and arrow, one bow for tapir and jaguar hunting being eight feet long.

F. S. Dellenbaugh,
Secretary, Explorers Club

November 5, 1913

QUOTATIONS

FREE SPEECH AND THE FACULTY

If there is one place that freedom of thought and speech should be safeguarded, it is in our college and university faculties. Presumably, no professor is obliged to wear the gag, yet it is worth observing that members of the Political Science Association have seen fit to appoint a committee "To examine and report upon the present situation in American institutions as to liberty of thought, freedom of speech and security of tenure for teachers of political science." It may be that this measure is preventive rather than remedial. It may be that these instructors in political sciences apprehend pressure by means of the various endowment, retirement and pensioning funds and take this method of safeguard against a possible dilemma arising therefrom. But it is even more probable that the unpleasant experiences of certain of their number who have come into collision, by one means or another, with sectarian prejudices, sinister interference or powerful political rings have not been without a prompting effect. With the exception of the state universities, most of our academic institutions are, of course, dependent on the liberality of private donors. It is well known that the terms of these gifts are often embarrassing—half a million to build a museum for the testator's collection of private hobbies, when the institution needs a dormitory or a library. The difficulty is that a donor who is placing an institution as deeply under obligation as may be represented by a gift of hundreds of thousands would need to be a very extraordinary and superior person not to conceive that some sort of deference was due his opinions in return. It speaks well for the grade of men who have thus far endowed our colleges that there has been comparatively little interference with the truths they teach, at least so far as the public has been informed—what private griefs they have we know not. But as lines of political cleavage grow more distinct, as they promise to do, it will become increasingly difficult to maintain this attitude of non-interference, and it may be that this action of the professors of political sciences will yet prove to have been well-timed.

The episode raises the whole question of intellectual liberty. Each age has thought it won, and each age has seen a new difficulty arise out of the vanquishing of the old. The universities, whatever their faults, have always been sanctuaries for independent minds. Unless they are so maintained, they will hardly be worth the name. The distinction between liberty and license in the citizen is recognized and enforced. The same principle underlies all academic independence.—*Boston Transcript.*

"FREEDOM" AND FEES

IT will, perhaps, do no harm to speak a little plainly of some aspects of the inquiry just instituted by the American Political Science Association into "the present situation in American educational institutions as to liberty of thought, freedom of speech, and security of tenure for teachers of political science." . . . The one point in the definition of the field of inquiry made by the association that is open to doubt and to discussion is "the security of tenure for teachers of political science." Here is where the assumptions to which we have referred come in. The gist of the matter is in the question how far a teacher of political science or of any other subject is entitled to retain his place and his pay when his teaching is not satisfactory to the trustees who are responsible for the institution in which he is employed.

That question is in some degree begged by the coupling of security of tenure with freedom of speech, as if the right to the former went with the right to the latter and as if a man not only had an inalienable right to teach whatever he chose, but a right equally inalienable to be paid for teaching it. That theory seems to us to need only to be stated to be rejected. It appears to us too clear to require discussion that the trustees of any institution of education ought not and can not surrender absolutely all control over the teaching in that institution to the men or the women who at any given moment happen to hold places in it. Nor is the matter changed materially if the trustees agree to turn over the control of the teaching to the faculty or to certain members of it. . . . Possibly the committee of the Political Science Association, with due study and reflection, in cooperation with like bodies, may be able to present some general rules or principles that may be useful. In the mean time it does no harm to suggest at the outset that there is no necessary, or even close, connection between the right to freedom of speech and the claim to be paid for speaking out of the funds of an institution the managers of which regard the speaking as mischievous.—*New York Times.*

SCIENTIFIC BOOKS

Lebensgewohnheiten und Instinkte der Insekten bis zum Erwachen der sozialen Instinkte, geschildert von O. M. REUTER. Vom Verfasser revidierte Uebersetzung nach dem schwedischen Manuskript besorgt von A. und M. Buch. R. Friedländer und Sohn, Berlin, 1913. Pp. xvi + 448; 84 text-figures.

This is the first of three volumes which Dr. O. M. Reuter planned to publish on the habits and instincts of insects. It treats only of the solitary species; the other volumes were to be devoted to the Socialia and to a general account of the sense-organs and the comparative psychology of insects. Most regrettably death has intervened to prevent the author from carrying out his plan and we are left with a single volume, which, however, is complete in itself.

The general account of insect behavior with which the work opens follows conventional lines. The activities are regarded as largely "instinctive," though the author is careful to state that some of them may properly be called "intelligent." Owing to the close association of instincts and bodily organization, he speaks of a "morphology of instincts and habits" and throughout the work views them from the evolutionary, or genetic standpoint. They are classified on a teleological basis, however, according to the problems which the insects have to solve in their daily lives. After an introductory chapter on the active and quiescent stages and the length of life of insects, the habits are arranged rather roughly under three heads, according as they subserve the purposes of nutrition, protection or reproduction.

The consideration of food-habits, though comprehensive, presents little that is new, the species being divided into omnivorous (Pantophaga), herbivorous (Phytophaga) and carnivorous (Sarcophaga). The two latter groups are each subdivided into Monophaga and Polyphaga, according as the insects derive their food from a single plant or animal or from several species. Two other groups of insects, the Necrophaga and Coprophaga, which feed on corpses and excrement, respectively, are also recognized. Parasitism is included under

the nutritive instincts, a conception which necessarily leads to a rather narrow and distorted treatment of this multiform phenomenon. The insects that feed on other animals are divided into three groups: typical prædators (Raptoria) parasitoid prædators (Parasitoidea) and true parasites (Parasita). The parasitoids include such forms as the so-called "parasitic" Hymenoptera, namely, the chalcis-flies, ichneumons, etc., which in their larval stage feed on the eggs, larvæ or pupæ of other insects, but as adults do not depart in structure from the non-parasitic members of their order, whereas the Parasita live even as adults on the bodies of certain hosts and also in this stage exhibit modifications of structure which adapt them to their peculiar life. At first sight this classification seems to be very satisfactory, but it breaks down on closer examination. If it were adopted one would have to classify the male Strepsiptera as parasitoids and their females as parasites. Moreover, Reuter's conception of parasitism is too narrow, because it includes only food parasitism and excludes phoresy (which Reuter, for some unknown reason, writes "Foresie") and brood parasitism. Reuter is, in fact, compelled to expand and modify his conception of parasitism as soon as he comes to consider the parasitic wasps and bees.

Commensalism, and more especially mutualism, are also somewhat too narrowly restricted by their inclusion under the nutritive instincts. Various forms of the migratory instinct are likewise considered under this head, as are also the various methods adopted by insects in protecting themselves from competing consumers. This latter subject forms a transition to the protective instincts proper. It is interesting to note that Reuter treats the toilet instincts ("Reinlichkeitsinstinkte") as protectives, since they have a sanitary value, no less than the methods of protecting the organism against excessive cold, heat, moisture, etc. Protection against enemies is distinguished as passive and active, the former comprising the cryptobiotic instincts (in the sense of Willey), protective coloration, mimicry, etc., the wonderfully diverse methods of forming the larval and pupal cases, autotomy and "death-feigning," while the actively protective behavior includes the use of the repugnatorial glands, the peculiar phenomena of "autohæmorrhœa," or emission of poisonous blood (often charged with cantharidin) from the joints of the legs in various larval and adult beetles, and phosphorescence, although this is in some cases passive (larval fire-flies) or connected with courtship (adult fire-flies). Reuter's treatment of the much-discussed subjects of protective resemblance and mimicry is very conservative. Any consideration of the many doubts which have been cast on these subjects by recent authors, especially in continental Europe, is omitted, as we should expect from the author's assumption that protective colors and devices are essentially passive, instead of being the stable results of once active adaptations.

Reuter devotes to what he calls the "instincts of metamorphosis" a chapter including the peculiar larval activities which leave the pupa in situations best adapted to the eclosion of the adult insect. This chapter clearly shows how impossible it is to draw a hard and fast line between the general physiological and morphological processes, on the one hand, and the instinct activities, on the other.

The reproductive instincts include the phenomena of courtship, that is, the exhibition by one sex of its peculiar movements, colors and structures, photogenesis, the use of the osmateria, or scent-glands, and such extraordinary pieces of behavior as that of the balloon-making male Empidid flies described by Girschner, Mik, Aldrich, Hamm and others, and finally oviposition and the extension of maternal and in rare cases also of paternal care to the eggs and larvæ.

The discussion of these and the foregoing subjects occupies about two thirds of the volume; the remainder is devoted to an excellent summary of the habits of the solitary wasps and solitary bees, and closes with two chapters on the adumbrations of social life noticeable in some non-social insects. The peculiar mixed arrangement of the materials relating to the wasps and bees is evidently intended to call attention to the parallelism or convergence in the phylogeny of their habits,

but it might have been better to have completed the account of each of these groups by itself and to have added a short chapter on the similarities due to convergence.

This very summary description of the contents of Reuter's work unfortunately fails to give any adequate conception of the large amount of very interesting and valuable reading it contains. As the first work to give a comprehensive survey of the habits of the solitary insects it is eminently successful. The writer has collated the essential facts from a very wide perusal of both the older and most recent literature on insect ethology, and has presented the matter in a very succinct and attractive style.

The volume ends with a well-selected bibliography of 60 pages and a good index. The bibliography includes many recent works on the social insects not cited in the text. There are few erroneous statements of fact like the one on p. 365, where it is said that ants appeared "in grossen Massen" in the Jurassic, immediately following the correct statement that "the existence of social Hymenoptera can not be demonstrated till Tertiary times." In the same paragraph we find the erroneous statement that termites occur in the Carboniferous.

The cuts in the text are mostly old, unattractive and poorly printed. Some of them set one to wondering why there are no good figures of many of our common insects, and why our author should be compelled to use, *e. g.*, the time-worn figure on p. 32 of the *Cicindela* larva, which is so small compared with its burrow that it could not possibly use its legs and dorsal horn in the manner described in the text. The number of typographical errors is considerable and many of them have not been corrected in the two pages of errata at the end of the volume. If it be true, however, as the reviewer is informed, that Reuter was blind for several years before his death, all of these errors and the poor selection of figures may be readily explained and pardoned.

W. M. WHEELER

Mind and Health, with an Examination of some Systems of Divine Healing. By EDWARD E. WEAVER, with an Introduction by G. STANLEY HALL. New York, The Macmillan Company. 1913. Pp. xv + 500. Price, $2.00 net.

The occasion for this book is the recent interest of some of the clergy in the practise of psychotherapy. After some account of the history, scientific basis and technique of psychotherapy, and a critical discussion of the merits of Christian Science, divine healing, "new thought," the Emmanuel movement, etc., the author reaches the conclusion that the church and its ministers can rightly and beneficially take a share in treating the sick. Religious faith and fervor, he urges, are a source of vitalizing energy which can be drawn upon for the maintenance and restoration of health. Character and health go together, and the minister of religion is, therefore, charged, to a degree, with the care of health. He should be acquainted with the scientific aspects of psychotherapy and should work in harmony with the physician.

R. S. WOODWORTH

Labrador. By WILFRID T. GRENFELL and others. New edition. New York, The Macmillan Co. 1913. $2.50 net.

The first edition of this standard work was recognized as a valuable addition to the literature on this practically unknown part of North America. The chapters on history, geology, Indians, birds, insects, mammals, etc., are admirable contributions from recognized experts.

While the new chapters by Dr. Grenfell have no scientific value, yet they are of popular interest, treating of animal life and of conservation. He sets forth pleasantly the lack of daring courage on the part of the bear and wolf, the domestication of the caribou, the food-value of the porcupine, the destructiveness of the lynx and the wiliness of the wolverine. On animal life he tells of the long winter experiences, when the bears sleep, the rabbits eat young birch, and the porcupine keeps to conifers. He adds: "Strangely enough none of the mammals rely on sight for protection. The difficulty of survival is in-

creased by constant warfare. The squirrel is never safe from the lynx, the caribou from the wolf, the rabbit from the fox."

As to conservation both sea and land game are steadily diminishing. The forests are fire-devastated, and immense waste continues in many directions. Indians and Eskimos are decreasing, and yearly bands escape starvation only through charity. Dr. Grenfell recognizes that the aboriginal inhabitants and the lower order of animals must go to the wall. He is however optimistic as to the development of Labrador; with the exploitation of the pulp forest for the whites, and by the reindeer herds for the natives.

The index completely ignores the new matter, an unfortunate oversight of the publishers.

A. W. Greely

BOTANICAL NOTES

THE FOURTH INTERNATIONAL BOTANICAL CONGRESS

Attention of botanists is called to the "first circular" in regard to the next International Botanical Congress, recently issued by the Organizing Committee.

Dear Sir and Colleague,

The International Botanical Congress, held at Brussels in May, 1910, decided, on the invitation of the Royal Society of London, that the next meeting of the congress, in 1915, should be held in London.

At a representative meeting of British botanists, held in London on May 10, 1911, a provisional bureau was nominated, consisting of three presidents (Professor F. O. Bower, Sir David Prain and Professor A. C. Seward) and a general secretary (Dr. A. B. Rendle). The bureau was empowered to cooperate with the permanent bureau of the Brussels Congress and to arrange for the appointment, in consultation with the British botanists, of an organizing committee. This organizing committee was elected at a general meeting of British botanists held in London on March 11, 1912; and at a second meeting held on May 17, an executive committee was appointed. A number of distinguished patrons of botany were also invited to lend their support to the congress.

The following general regulations for the conduct of the congress have been approved by the executive committee:

1. The Fourth International Botanical Congress shall be held in London from Saturday, May 22, to Saturday, May 29.

2. Membership of the congress shall be conditional upon subscribing to its regulations and the payment of a subscription of fifteen shillings. Members will receive all the publications of the congress. Ladies accompanying members may attend the meetings and excursions of the congress on payment of ten shillings each.

3. The work of the congress shall include the different branches of botanical science; and the congress will also carry on the work on (1) nomenclature, and (2) bibliography and documentation, left over from the previous meeting.

The permanent bureaus entrusted with the work concerned with (1) nomenclature, and (2) bibliography and documentation will act in conjunction with the executive committee.

4. Any language may be used in the discussions; if desired by the members, propositions shall be translated forthwith into English, French and German. English shall be the official language of the congress.

Particulars of meetings, discussions, excursions, etc., will be issued later.

American botanists are reminded that it is not too early to begin making arrangements for this congress. Communications may be addressed to the general secretary, Dr. A. B. Rendle, keeper of the department of botany, British Museum, Cromwell Road, London, England.

A NEW KIND OF BOTANICAL TEXT-BOOK

It is not often that the reviewer of books finds one of a new type, and especially is this true in regard to elementary text-books in science; yet in John G. Coulter's "Plant Life and Plant Uses" (Am. Book Co.) we find just such a case. It is so unlike the usual book designed for beginners in botany that the author allows the use of the word text-book only with particular limitations and restrictions. Avowedly intended as "a foundation for the study of agriculture" and "domestic science" the author has not al-

lowed this purpose to change materially the presentation of "the large essentials of plant life." "The effort is to include what has proper place in the education of *all* young people," and he distinctly excludes those special matters which are best relegated to agriculture, horticulture, domestic science, forestry, etc. In other words, we have here what the author believes all young people should know about plants as a general foundation for the subjects named, or even as a preparation for college botany. The present reviewer is in hearty accord with this educational theory, and he believes that in all well-considered schemes of education pure science must precede applied science.

The book is written in an easy, almost conversational style, and one wonders just how it is likely to be used by the ordinary teacher. It can scarcely be "recited" by the pupil, and possibly this may be a point in its favor. Perhaps this is why the author has added questions after the chapters, usually a feature of doubtful value, from the temptation it offers to the illy-prepared teacher to hold the book and ask the questions noted down before him.

Looking through the book, one is struck by a freshness of statement, showing that the author feels that he has a message for the high-school pupils of the country, and this continues with unabated enthusiasm from the first paragraph of the introduction to the closing paragraph of the book. It should do much to place high-school botany in this country upon a higher plane than it has ordinarily attained.

A NICE LITTLE DIATOM BOOK

One of the most attractive little books that we have seen in many a day is one entitled "Bacillariales" by H. v. Schönfeldt, and published by Gustav Fischer, of Jena. It is volume 10 of the series of booklets now in course of publication entitled "Die Süsswasserflora Deutschlands, Osterreichs un der Schweiz" and edited by Professor Doctor Pascher, of Prag. There are to be sixteen of these booklets, bound in limp cloth, each measuring about 11×19 cm. The book before us gives ten pages to structure, cell-contents, movements, reproduction, collecting, mounting and the literature of the group. Then follow 163 pages of systematic descriptions, the general treatment following that by Schütt in Engler and Prantl's "Natürlichen Pflanzenfamilien." Fourteen pages are given to the round diatoms (Centricæ), including eight genera and thirty-five species, while about 150 pages are given to the long diatoms (Pennatæ) in which are included about 40 genera and 390 species. These figures emphasize the statement often made that the round diatoms are mostly marine, and the long diatoms mostly inhabitants of fresh waters. Probably the truth is that in fresh waters we find many more long diatoms, because there are many more of them in the world at large, but this does not wholly account for the great disparity in numbers.

There are 379 cuts in the text, which must help the student greatly in his attempts to understand the structure and especially the markings of the cell-walls. A well-arranged index of scientific names closes this handy little book. One can not lay down this book without the wish that some day we may have something like it for this country.

CHARLES E. BESSEY
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SPECIAL ARTICLES

SUSCEPTIBILITY GRADIENTS IN ANIMALS

THE writer has called attention in several papers[1] to the existence of axial gradients in rate of metabolism in planarians and other forms and their significance in relation to polarity. During the past summer in the course of other work at Woods Hole the opportunity presented itself to examine various forms belonging to different groups and various embryonic and larval stages for the existence of such gradients.

The method used was that of determining the relative susceptibility of different regions

[1] *Jour. Exp. Zool.*, XII., 1912; *Arch. f. Entwickelungsmech.*, XXXV., 1913; XXXVII., 1913.

of the body to certain narcotics and poisons, KCN, alcohol and ether being chiefly used. To concentrations of these and various other substances which kill within a few hours without permitting any acclimatization the susceptibility varies in general with the rate of metabolism, or of certain fundamental metabolic processes, *i. e.*, the higher the rate of these processes the greater the susceptibility and the earlier death or cessation of movement occurs.[2] Death in these reagents is usually followed very soon, often almost at once, by rounding, separation or disintegration of the cells, so that the time of death can be approximately determined by visible changes of this kind. Results obtained in this manner can be controlled by removing the animals from the solution at different periods and determining when recovery ceases to occur and experience has shown that these two methods of procedure give essentially similar results. In this way the following forms were examined.

In *Nereis virens* the regional susceptibility of developmental stages from the beginning of cleavage to the late trochophore was determined. In the early cleavage stages the micromeres are more susceptible to KCN 0.005 *m.* than the macromeres. They not only disintegrate before the macromeres when the eggs remain in the solution, but if the eggs are returned to sea water at the proper time the micromeres alone are killed and the macromeres recover and resume division, giving rise to defective larvæ.

At the stage when gastrulation is nearly completed the somatic plate region is apparently the most susceptible region of the embryo, and by return to water at the proper time it is possible to obtain larvæ which do not elongate posteriorly and do not form the three larval segments. If the embryos at this stage are left for a longer time in KCN before return to water, both somatic plate and some or all of the macromeres are killed and the intact portion consists of more or less of the ventral portion of pretrochal and post-trochal ectoderm with or without a part of the macromeres. Evidently the most susceptible regions at this stage are first the somatic plate, and second, the dorsal part of the pretrochal region and the macromeres.

In the developing egg of another annelid, *Chætopterus pergamentaceus*, the relative susceptibilities of different regions are much the same. In the early stages the animal pole shows the highest susceptibility and in later stages a second region of high susceptibility appears in the somatic plate. In still another polychæte, *Arenicola cristata*, the apical region and somatic plate of the young trochophores are the most susceptible regions. The early cleavage stages of this species were not obtained.

In *Nereis* and *Chætopterus* the region about the animal pole is clearly the region of greatest susceptibility, *i. e.*, of greatest metabolic activity in the early stages of development. Later the activity in this region becomes relatively less in *Nereis* as differentiation of the apical larval region advances and the somatic plate becomes the most active region of the egg. But in *Chætopterus* the apical region retains its susceptibility to some extent at the completion of gastrulation, and this region and the somatic plate appear as distinct regions of high susceptibility. In other words, at the beginning of development an axial metabolic gradient exists with the region of highest rate about the animal pole, but as development proceeds this gradient is altered from its primary simple form by the increase in activity of the cells which give rise to body segments and later by decrease in activity in the animal pole region.

In the egg of the sea urchin *Arbacia* in KCN 0.005 *m.* a distinct susceptibility gradient was observed during cleavage, death and disintegration beginning at one region of the egg and proceeding along an axis, but it was not possible to determine whether the region of highest susceptibility was always the animal pole, though in many cases it certainly was. In the later gastrula and prepluteus stages this simple gradient was complicated by the appearance of high susceptibility in the re-

[2] Child, *Jour. Exp. Zool.*, XIV., 1913.

gions where the arms were beginning to develop.

Since in *Nereis, Chætopterus* and *Arbacia* the different susceptibilities of different regions of the developmental stages make it possible to kill with more or less exactness certain parts of the embryo while other parts may recover and continue development, this method may prove of some value in further investigation of the regulatory capacities of the less active regions when isolated from the influence of the more active.

The adult forms of a number of species from various groups were examined for a susceptibility gradient. In the hydroid *Pennaria tiarella* with KCN 0.0025 *m.* and 0.005 *m.* such a gradient appears very clearly in the body of the hydranth, death and disintegration beginning at the distal end of the manubrium and proceeding proximally. A similar gradient exists in the medusa buds of this species. Besides this it was observed that the full-grown hydranths at or near the tips of stem or branches were in general more susceptible than the more proximal. This difference may be due to external factors such as the lower oxygen or higher CO_2 content of the water about the more proximal hydranths in consequence of the greater number of hydranths in a given area, but it seems more probable, in the light of various data concerning the polarity of plants, that this difference in susceptibility of distal and proximal hydranths is the expression of an axial gradient in the colony.

In several other species of hydroids examined at Woods Hole and at La Jolla, California, among them *Tubularia crocea* and *Corymorpha palma* the gradient in the hydranth body is similar to that in *Pennaria.*

The ctenophore *Mnemiopsis leidyi* shows a distinct gradient in susceptibility along each row of swimming plates. The susceptibility of these animals to KCN is very high and most experiments were made with KCN 0.0000375 *m.*—00005 *m.* Rhythmic movement of the plates ceases first at the central end of each row, *i. e.,* the end nearest the apical sense organ, and last at the peripheral end. Before movement has entirely stopped in the apical region the rhythm of the plates in the peripheral half or third of the row becomes different from the central rhythm, being usually more rapid and in some cases irregular or periodic. In two cases a perfectly distinct reversal in direction of the impulse was observed at the peripheral end of a row after movement at the central end had ceased. In this case the impulse started at the extreme peripheral end of the row and traveled some distance in the central direction, finally dying out. This continued for an hour or more before movement at the peripheral end ceased.

This susceptibility gradient is undoubtedly a gradient in the nerve and not in the plates themselves, for the plates do not die in KCN until long after rhythmic movement ceases, and as long as they remain alive direct contact stimulation of single plates produces slight movements of the plate stimulated. However, a slight susceptibility gradient does exist in the plates themselves as is evident from the fact that the plates at the central end of the nerve die first and death proceeds peripherally. The time of death is readily determined, for when they die the plates lose their interference colors and become white and opaque.

As regards the general ectoderm of *Mnemiopsis,* it is difficult to determine the time of death accurately, but observations thus far indicate that the disintegration of the ectoderm proceeds from the apical region.

During the course of my observations on susceptibility gradients Dr. Tashiro called my attention to his discovery of a quantitative gradient in CO_2 production in the claw nerve of the large spider crab, *Libinia canaliculata:* this is a long nerve which readily separates into small strands and is therefore favorable for observation of any structural changes which might occur in connection with death in solutions of narcotics. The nerve is mixed but is believed to consist largely of efferent fibers.

Since there is some evidence in the work of various authors that a gradient of some sort exists in the nerve, the attempt was made to

determine whether a gradient would appear in the structural death changes. A number of nerves were observed in various concentrations of KCN from 0.001 *m.* to 0.01 *m.* In these solutions the fibrillæ become after a time irregular in outline and more or less varicose so that the strand appears more or less granular instead of fibrillar like the fresh living nerve. The preparations showed some indications of the progression of the change from the central to the peripheral end of the nerve, but the changes were so slight that the possibility of a subjective factor being concerned could not be neglected. In the attempt to obtain more distinct structural death changes other narcotics were used, and it was found that in ethyl ether the fibrillation almost completely disappeared and the strands became very distinctly granular in appearance in consequence of irregular swelling and varicosity of the fibrils. In 1 per cent. ether or somewhat lower concentrations these changes occur, slowly requiring several hours for completion, and a very distinct gradient in their occurrence is visible. The change from fibrillar to granular appearance begins at the two ends of the nerve very soon after it is brought into the solution, and a distinct gradient in this change can be seen extending a few millimeters peripherally from the central end and a shorter distance centrally from the peripheral end. This first change remains limited to the two terminal regions of the nerve and is undoubtedly associated with the stimulation and injury resulting from severing the nerve at these two points.

Later, however, the change begins to progress along the nerve from the central toward the peripheral end, but the change at the peripheral end progresses only very slowly or not at all in the central direction. From this time on a distinct gradient in the change is visible until it has progressed along the whole length of the nerve. Except in the terminal region adjoining the peripheral cut end the death change always progresses in the peripheral direction. The peripheral third of the length may be entirely unchanged at a time when the central third or more has completely lost its fibrillar appearance. When long strands are so arranged that central and peripheral regions are side by side in the same field of the microscope the differences between the two regions are very striking. If the nerve is crushed or injured at any point short gradients appear on both sides of the injury, but do not extend to any great distance before the general change reaches this region in its progress peripherally.

The existence of this centro-peripheral gradient in the death changes of the nerve fiber in narcotics must mean that a gradient of some sort exists in the living nerve and if the action of the narcotics is of the same character here as in other cases we must conclude that this gradient is associated with metabolism and that the rate of metabolism or of certain metabolic processes is in general higher at the central end and decreases peripherally in this nerve.

That metabolic gradients occur very widely if not universally, at least during the earlier stages of development in axiate organisms and structures, is evident from the data of embryology. The so-called law of antero-posterior development must be the expression of an axial metabolic gradient. And as regards plants there is a large body of evidence which indicates that the vegetative tip possesses a higher rate of metabolism than other regions of the same axis. Even in the unicellular body of the ciliate infusoria and in various other cells which show a morphological polarity the writer has observed a susceptibility gradient. In view of the facts it is impossible to doubt that such gradients are in some way closely associated with polarity in organisms, and various lines of experimental evidence which can not be considered here indicate that they constitute the dynamic basis of polarity. There are, moreover, many facts which suggest that the establishment of a gradient of this kind is the first step in individuation in axiate organisms.

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